Abstract

December 15 (Thursday)

10:20-10:35

O-01: New Horizon of Low Temperature Physics in the Twenty First Century

Hiroshi Fukuyama (Department of Physics, University of Tokyo)

This conference is the first opportunity to meet each other and exchange ideas for all the members involved in the project, “Physics of New quantum phases in Superclean Materials”. The term of this project is for five years (2005 – 2009) being financially supported by MEXT of Japanese government as one of Scientific Researches in Priority Area (No. 450). Research subjects we cover here, such as strongly correlated quantum fluids in low dimensions, superfluid turbulence, quantum gases with internal degrees of freedom, spin – triplet superconductivity and ring exchanges, may look relatively diverse at first sight. However, they are linked by two common key words, i.e., the low temperature limit and superclean systems. Behind these phenomena, there should be several new fundamental concepts of physics. The aim of this interdisciplinary project is to establish some of them.

Group A02

10:45-11:15

O-03: Search for Novel Quantum Phenomena in ^{4}He Confined in Nano - porous Media

Keiya Shirahama (Department of Physics, Keio University)

Bosons under periodic or random potential are expected to show various exotic phases, such as Mott insulator, Bose glass and supersolid. ^{4}He in nano - porous media provides us with an exciting opportunity to study strongly correlated Bose liquid and solid under confinement potential.

We have been investigating quantum properties of ^{4}He in nano - porous materials, employing torsional oscillator, pressure, ultrasound, and heat capacity measurements. In this talk I will review the current status and future plans of our research works. I will focus on several topics, including (1) open questions in our past studies of the quantum phase transition of ^{4}He in a nano - porous glass, (2) an ongoing heat capacity study for the same system, and (3) some preliminary results in search for a quantum fluid state in hydrogen (H_2) confined in the porous glass.

11:15-11:35

O-04: Ultrasonic Study for Superfluidity of ^{4}He Filled in a Nano - porous Glass

Masaru Suzuki

(Department of Applied Physics and Chemistry, University of Electro - Communications)

Recently, Yamamoto et al. have carried out torsional oscillator measurements for ^{4}He filled in a nano - porous glass with pores of 2.5 nm in diameter (Gelsil), and reported a large suppression of superfluidity at high pressure. In order to study the mechanism of the superfluid suppression, we have carried out ultrasonic measurements for ^{4}He filled in the same nano - porous glass. We have clearly observed an increase in the sound velocity due to the superfluid decoupling. At zero pressure, the superfluid transition temperature T_c is suppressed to 1.4 K from the bulk lambda point (2.17 K). However, T_c in the present experiment shows a much weaker pressure dependence as compared with Yamamoto et al., and terminates at the freezing curve. At present, the origin of this different behavior is not clear.

11:35-12:05

O-05: One-Dimensional ^{4}He and ^{3}He Quantum Fluids Formed in Nanopores

Nobuo Wada (Department of Physics, Nagoya University)

We have been studying ^{4}He and ^{3}He adsorbed on nanopores that have regular pore structures. In one-dimensional (1D) nanopores, ^{4}He fluid film tubes are formed on nanopore walls covered with about one atomic inert (solid) helium layers. The 1D state of the ^{4}He fluid tubes was examined by observing the 1D phonon heat capacity. Dilute ^{3}He film nanotubes formed in the nanopores preplated with ^{4}He layers shows dimensional crossover from the 2D Boltzmann gas at high temperatures to 1D gas state that shows the T – linear heat capacity of the degenerate ^{3}He fluid at sufficiently lower temperatures.

12:05-12:25

O-06: Ground State of ^{3}He Atoms in a Narrow Tube

Dai Hirashima (Department of Physics, Nagoya Univeristy)

The ground state of ^{3}He atoms confined in a narrow tube is studied with the variational Monte Carlo method. It is found thatthe atoms condense into a liquid state in the dilute limit in a certain range of the tube radius. Relevance of this finding to the recent experiment on ^{3}He atoms in nanopores (by Taniguchi et al.) is discussed. Connection of the present results with recent studies of ultracold atoms in a quasi-one dimensional trap is also pointed out.

Group A03

13:40-14:10

O-07: Quantum Fluid Dynamics in Superfluid Helium and Atomic Bose-Einstein Condensates

Makoto Tsubota (Department of Physics, Osaka City University)

We have studied quantum fluid dynamics in superfluid helium and atomic Bose-Einstein condensates. We will discuss two topics from our recent works. The first is finding the Kolmogorov spectrum in quantum turbulence. Recently there have been growing interests in the similarity between classical and quantum turbulence. The numerical analysis of the Gross-Pitaevskii equation shows that quantum turbulence takes the Kolmogorov spectrum that is the most important statistical law in turbulence. The second is physics of quantized vortices in atomic Bose condensates. We will discuss the vortex lattice formation and the vortex structure in two-components condensates.

14:10-14:30

O-08: Study on the Quantum Turbulence in Superfluid ^{4}He generated by a Vibrating Wire

Hideo Yano (Department of Physics, Osaka City University)

We have studied the flow of superfluid ^{4}He generated by a vibrating wire. The response of the vibrating wire indicates that the flow becomes turbulent state above a certain velocity of the wire. The turbulent flow should be caused by unstable expansion of vortex strings attached to the wire. In the turbulent-flow regime, however, the vortex strings seem to be confined into a finite size. This confinement suggests that entanglement and reconnection prevent vortex strings on the wire from expanding infinitely. The switchings between a normal flow and a turbulent flow appear in the response of the wire at low temperatures. The switchings are expected to reflect the vortex dynamics directly such as expansion, entanglement, and reconnection.

14:30-15:00

O-09: Bose-Einstein Condensation with Internal Degrees of Freedom

Masahito Ueda and Hiroki Saito

(Department of Physics, Tokyo Institute of Technology)

Bose-Einstein condensates of alkali atoms have internal degrees of freedom arising primarily from electronic spin. This degrees of freedom can be utilized to manipulate and probe local spin textures. The high spin values also lead to new quantum phases such as the cyclic phase. We review some of our recent studies on the statistics and dynamics of spin-1 and spin-2 BECs.

15:00-15:20

O-10: Experimental Study of Atomic Bose-Einstein Condensates with Internal Degrees of Freedom

Takuya Hirano and Takeshi Kuwamoto (Department of Physics, Gakushuin Univeristy)

Optically trapped atomic Bose-Einstein condensates (BEC) offer a fascinating testing ground for a superfluid with internal degrees of freedom, because, in contrast to magnetic traps, a far – off resonant optical trap confines atoms in all spin states. We have studied the spin-mixing dynamics of optically trapped ^{87}Rb spin – 2 BEC at various magnetic field strengths, and observed population oscillations of the m_F components during the evolution of spin-mixing. We have also realized optically confining binary BEC (simultaneous trap of $F = 1$ and $F = 2$), which have antiparallel magnetic dipole moments. We found that the two components tend to separate spatially and the center of mass oscillations were observed.

Group A04 (Part 1)

15:40-16:10

O-11: Novel Quantum Phenomena Characteristic of Spin-Triplet Superconductivity

Yoshiteru Maeno

(International Innovation Center and Department of Physics, Kyoto University)

The objective of this research is to explore novel superconducting phenomena characteristic of the spin-triplet pairing in the super-clean ruthenate, Sr_2RuO_4. Two main topics will be pursued: One is to control the order parameter of the triplet superconductivity by magnetic fields and induce novel phenomena such as the rotation of the d-vector, collective modes of Cooper pairs, and superconducting multiple phases. The other is to explore new superconducting phenomena mainly in eutectic crystal systems containing Sr_2RuO_4. The experimental observations of zero-energy surface states, unusual proximity effects, and chiral edge current are examples.

To achieve these goals, I will collaborate tightly with K Ishida and K. Miyake on the first topic, and with H. Kambara and Y. Tanaka on the second topic. We intend to promote active interactions with researchers working on the spin-triplet superconductivity, as well as on the superfluidity of ^{3}He and on the BEC of cold atoms.

16:10-16:30

O-12: Plan of the Study of Superconducting Sr_2RuO_4 by Resonance Experiments

Kenji Ishida (Department of Physics, Kyoto University)

We plan following experiments on Sr_2RuO_4 to understand more deeply about the superconducting (SC) properties.

1) Knight shift measurements in small field to determine the d – vector in zero field.

2) Measurements of Knight shift and nuclear spin-lattice relaxation rate $1/T_1$ in the region close to H_{c2}, where the specific heat shows the double-peak behavior.

3) Muon – spin – relaxation measurements on eutectic crystals of Sr_2RuO_4 to understand the origin of the spontaneous field in the SC state.

4) Measurements of $1/T_1$ in the SC state under various fields to understand the vortex state and to detect the collective mode related to the SC pairs and the multiphase behavior.

Recent progress on the Knight-shift measurement will be shown in my presentation.

16:30-16:50

O-13: Effect of Spin-Orbit Interaction in Spin-Triplet Superconductor: Structure of d-vector and Anomalous ^{17}O – NQR Relaxation in Sr_2RuO_4

K. Miyake and H. Kohno (Department of Materials Engineering Science, Osaka University)

The spin-orbit (SO) coupling in the spin-triplet superconducting state is calculated by extending the method for the dipole-dipole coupling given by Leggett in the superfluid ^{3}He. It is shown that the SO coupling works only in the equal-spin pairing (ESP) state to make the pair angular momentum $\hbar\mathbf{L}$ and the pair spin angular momentum $i\mathbf{d}\times\mathbf{d}^*$ parallel with each other. The SO coupling gives rise to the internal Josephson effect in a chiral ESP state as in the superfluid A phase of ^{3}He, solving the problem of the anomalous relaxation of ^{17}O – NQR and the structure of $\mathbf{d}$ – vector in Sr_2RuO_4.

16:50-17:10

O-14: Anomalous Proximity Effect in Triplet Superconductor Junctions

Yukio Tanaka (Department of Applied Physics, Nagoya University)

In unconventional superconductor junctions, reflecting the internal phase of the pair potential, charge transport becomes essentially phase sensitive. The most dramatic effect is the manifestation of the zero bias conductance peak (ZBCP) in tunneling spectroscopy due to the formation of the mid gap Andreev resonant state (MARS). Although it was revealed that the MARS influences significantly on various charge transport phenomena, preexisting theories are limited in the ballistic transport regime. Recently, we have developed a theory which is available for diffusive normal metal (DN) / unconventional superconductor junctions based on the Nambu-Keldysh Green's function theory [2]. Applying this theory for triplet superconductor junctions, we have revealed very unusual charge transport properties. Contrary to the singlet superconductor junction case, the MARS is shown to enhance the proximity effect in the DN. The total resistance of the junction is drastically reduced. The local density of states (LDOS) in DN has a zero-energy peak. These striking features manifest the presence of novel proximity effect peculiar to triplet superconductor junctions. The pair amplitude f as a function of energy in DN, satisfies an anomalous relation, $f(e) = -f^*(-e)$, contrary to that in singlet superconductor junctions case where $f(e) = f^*(-e)$,. Our results are relevant to Sr_2RuO_4, which is considered to have a $p_x + ip_y$ – wave symmetry.

[1] Y. Tanaka and S. Kashiwaya, Phys. Rev. Lett. **74**, 3451 (1995); S. Kashiwaya and Y. Tanaka, Rep. Prog. Phys. **63**, 1641 (2000).

[2] Y. Tanaka et al., Phys.Rev. Lett. **90**, 167003 (2003); Phys.Rev. B **69**, 144519 (2004).

[3] Y. Tanaka et al., Phys.Rev. B **70**, 012507 (2004); Phys. Rev. B **71**, 094513 (2005).

[4]Y. Tanaka et al., Phys. Rev. B **72,** 145031 (2005).

17:10-17:30

O-15: STM / STS Experiments of Sr_2RuO_4 and Related Compounds

Hiroshi Kambara (Department of Physics, University of Tokyo)

By using an ultra-low temperature STM (20 mK, 6 T, UHV), we are studying the spin-triplet superconductivity in Sr_2RuO_4 and related compounds such as Sr_2RuO_4-Ru (3-K phase) or Sr_2RuO_4-$Sr_3Ru_2O_7$ eutectics, etc. Until now we have observed the superconducting gap at an inhomogeneous surface of Sr_2RuO_4 and nano-scale line defects which exist only in the 3 K phase samples. In order to study novel phenomena characteristic of the spin-triplet superconductivity, we are planning to measure proximity effects and Andreev bound states in these materials using the STS technique.

December 16 (Friday)

Group A04 (Part 2)

9:00- 9:30

O-16: Anisotropic Superfluid ^{3}He in Some Circumstances

Osamu Ishikawa (Department of Physics, Osaka City University)

The super clean sample of ^{3}He can be obtained by performing experiments at ultra low temperatures with a suitable preparation of it in advance. The ordered phase in liquid of ^{3}He is known as superfluid of strongly interacting Fermi particles that has anisotropic part in order parameter. So the superfluid ^{3}He possesses a possibility of possessing different ordered phases even in bulk liquid. Putting ^{3}He in some circumstances of confined geometry or under rotation etc., new phase would appear or new phenomena be observed. Recent results about superfluid phase in aerogel and in thin cylinder under rotation will be talked with a plan for the future.

9:30- 9:50

O-17: Spin dynamics and vortex state of ^{3}He-A studied by NMR line width change under Rotation

Y. Kataoka, M. Yamashita, K. Izumina, O. Ishikawa, & M. Kubota

(Institute for Solid State Physics, University of Tokyo)

Spin dynamics and Vortex state of superfluid ^{3}He-A under rotation has been studied by the main ^{3}He NMR line width change under up to more than twice as fast rotational speed as ever reported. We discuss the three reduced temperature τ ranges where the line width broadening $\Delta\Gamma(\Omega)$ changes its τ dependence, for the first time from the measured experimental data. This three reduced temperature ranges had been predicted by the theoretical work by Fomin and Kamenskii (1982) by considering individual vortex lines and spin diffusion and spin wave phenomena. We report our preliminary NMR line width change measurements for different rotational speeds, Ω's as well. The results are consistent with so far reported results within the overlap range and it reveals different Ω_n dependence for each of the three reduced temperature ranges.

9:50-10:10

O-18: Boundary and Impurity Effects on Anisotropic Superfluids and Superconductors

Katsuhiko Nagai (Faculty of Integrated Arts and Sciences, Hiroshima University)

It is well known that anisotropic superfluids are affected by the presence of boundary and nonmagnetic impurities.

A typical example of boundary effect is the formation of zero-energy surface bound state. The bound state in d-wave superconductors is well known as an origin of zero-bias anomaly in tunneling experiments. We have recently found that the surface bound states in the B phase of superfluid ^{3}He dominate the temperature and frequency dependence of the transverse acoustic impedance, which is in agreement with experiments by TIT group.

We have been interested also in the impurity effects on liquid ^{3}He in aerogel and possible p-wave superconductors. We report on the sound propagation in liquid ^{3}He in aerogel and also on electronic Raman spectra of strontium ruthenate to discuss the impurity effects on the collective modes.

Group A01

10:10-10:40

O-19: Quantum Phases in Two Dimensional Helium Three

Hiroshi Fukuyama (Department of Physics, University of Tokyo)

I will discuss current status and future plans of our experimental studies of novel quantum phases in 2D ^{3}He. So far, we found four distinct phases (regions I-IV) depending on areal density in 2D ^{3}He adsorbed on graphite surface preplated with monolayer ^{4}He. They consist of a fermi fluid (region I), an anomalous fluid (region II), a fluid with a super heavy quasiparticle mass (region III) and a phase with a ferromagnetic tendency (region IV). The universality class of the localization transition, boson substitution effect, dynamical properties of spin and mass flows will be studied for each phase to elucidate its microscopic nature using high-precision heat capacity measurements, pulsed NMR and vibrating substrate techniques.

10:40-11:00

O-20: Two-dimensional Fermion System in Triangular Geometry and its Future

Masao Ogata (Department of Physics, University of Tokyo)

So far, we have been studying various aspects of strongly correlated systems. As a relating subject, we studied electron systems on two-dimensional triangular lattice. In this case, spin- and charge-degrees of freedom are not separated, which is not consistent with experimental results of the Fukuyama's group about the second-layer He atoms absorbed on graphite. We are going to develop theoretical studies about the two-dimensional fermion systems; for example, specific heat and susceptibility, possibility of spin-charge separation, and dynamics of vacancies.

11:20-11:50

O-21: Novel Quantum Phase and Criticality

Masatoshi Imada (Institute for Solid State Physics, University of Tokyo)

New type of quantum criticality emerges when first order transitions at finite temperatures shrink to quantum criticality in strongly correlated electron systems. We discuss several examples including metal-insulator transitions. It does not follow Ginzburg-Landau-Wilson scheme of phase transitions, while it satisfies scaling laws. The significance of the new universality class is discussed with its consequences and comparison with experimental results. After quantum transitions, highly quantum phases such as quantum spin liquid sometimes appear in materials with so-called geometrically frustrated structure. Theoretical insights obtained from numerical studies will be highlighted.

11:50-12:10

O-22: Spin Disorder in a Bulk Triangular Lattice Antiferromagnet

Satoru Nakatsuji (Department of Physics, Kyoto University)

We have recently found a spin disordered state in two dimensions in $NiGa_2S_4$, a bulk insulating antiferromagnet on a triangular lattice. Despite strong antiferromagnetic (AF) interactions of ~ 80 K, no magnetic long-range order has been observed down to 0.35 K where we instead find nano-scale quasi-static correlation. The spin disordered state appears on cooling through highly degenerate states with an entropy plateau, and exhibits gapless linearly dispersive modes, suggesting coherence beyond the two-spin correlation length.

12:10-12:30

O-23: Quantum Critical Behavior in Geometrically-Frustrated Systems

Yukitoshi Motome (RIKEN)

Geometrical frustration suppresses long-range ordering, and in some cases, gives rise to a quantum critical point where the critical temperature goes to zero. Here we investigate a fingerprint of the 'quantum critical' behavior in a microscopic 'classical' spin model, antiferromagnetic Heisenberg model on pyrochlore lattice in applied magnetic field. Our model exhibits a metamagnetic 'quantum critical' point and a spin 'pseudogap' state with preformed local order in the paramagnetic state. By tuning the critical temperature, we can study how this 'pseudogap' state turns to be a gapped, true long-range ordered phase. Effects of thermal and quantum fluctuations are discussed.

12:30-12:50

O-24: Mott Transition and Spin Degrees of Freedom in Q-2D Organics

K. Kanoda (Department of Applied Physics, University of Tokyo)

The layered organics, κ - $(ET)_2X$ are model systems for the study of interacting half-filled-band electrons on anisotropic triangular lattice. The bandwidth and the Coulomb repulsion energy are comparable in the κ - $(ET)_2X$ family, which is situated around Mott transition. In this symposium, we will present our recent findings on the Mott transitions; the criticality in 2D Mott transition is unconventional and the spin frustration affects the profile of the Mott phase diagram with an AF phase replaced by a spin liquid phase.

Group A05

14:00-14:30

O-25: Magnetism and Crystal Control in Quantum Solid

H. Ishimoto (Institute for Solid State Physics, University of Tokyo)

After a short briefing on the whole program in collaboration with Kyoto Univ. and TIT, my own group's recent activity and future plans will be presented. A second layer ^{3}He on exfoliated graphite is known to form a solid at the 4/7 density of the underneath layer. The ground state of so called 4/7 phase could be a gapless spin liquid from the heat capacity and susceptibility measurements. Then how looks like the behavior under high magnetic fields? The first magnetization measurement under high magnetic fields on this phase has been made by use of a double gradient field Faraday magnetometer. The preliminary results up to 10 T will be given.

14:30-14:50

O-26: Nuclear Ordered Solid ^{3}He: Experimental Study at Kyoto University

Yutaka Sasaki

(Research Center for Low Temperature and Materials Sciences, Kyoto University)

Nuclear ordered solid ^{3}He has been attracted interests as a unique material to investigate magnetism of the strongly correlated Fermion system. Successful understandings with multiple spin ring exchange model can be considered as one of the most beautiful outcome of the ultra low temperature physics. We can do a serious comparison between theory and experiment, due to the fact that this system is practically free from impurity. Our ultrasound measurement cast an open question on how accurate the current understanding is. On the other hand, NMR and MRI measurement showed various dynamic and static phenomena that were explained reasonably well with magnon theory based on the multiple spin exchange model. In this talk, I will review the current status of our experimental studies and will discuss about the future perspective in this research program.

14:50-15:10

O-27: Crystal growth of clean and dirty solid Helium

Yuichi Okuda and Ryuji Nomura (Department of Physics, Tokyo Institute of Technology)

Solid ^{4}He is grown in superfluid at very low temperature. It is an ideal system to study the fundamental aspect of crystal growth and the equilibrium shape of the crystal. We plan to study 1) the anomalously fast growth rate of this clean bulk solid by optical and ultrasonic techniques. 2) At the same time, we will study the crystal growth and shape in disordered geometries produced by aerogels. Roughening transition of such dirty quantum solids is a challenging theme. 3) The macroscopic size ^{4}He crystal is largely deformed on the ground due to the gravity. The free fall experiment of the crystal is another interesting topic to search for the true crystal shape.

15:30-16:00

O-28: Exotic Magnetism Induced by Ring Exchange

Tsutomu Momoi (RIKEN)

We discuss possibility of finding quantum spin liquid or exotic phase in magnetic systems which have strong magnetic frustration due to competing interactions. We mainly investigate magnetism induced by ring exchange interaction. It was recently confirmed that quantum solids and oxides have non negligible ring exchange interactions. The nature of the magnetism induced by ring exchange is, however, not well understood. We discuss how exotic quantum phases such as chiral phase and nematic phase can be induced by ring exchange.

16:00-16:20

O-29: Magnetism on Generalized Partial Line Graphs

Kenn Kubo (Department of Physics and Mathematics , Aoyama Gakuin University)

Electrons in lattice models some of whose energy bands are dispersionless (flat) are known to show interesting physical properties when the interactions between electrons are introduced. Antiferromagnets on those lattices are also known to have strong frustration. We have recently proposed a new class of flat band systems which we call partial line graphs (PLG). In this talk we report on magnetism on two examples of generalized PLG. One example is the Hubbard model on the PLG of the honeycomb lattice. We numerically diagonalize the finite clusters and search for the ferromagnetism. Another example is the antiferromagnet on a generalized PLG of the square lattice. This model is known to exhibit ferrimagnetism in a limit. We investigate numerically the ground state phase diagram of this system. Results are still preliminary.

16:20-16:40

O-30: Quantum Dynamics under Time-dependent External Fields

Seiji Miyashita (Department of Applied Physics, University of Tokyo)

We will discuss properties of quantum dynamics of order parameters of the magnetic systems and related lattice gas systems under time-dependent fields, and investigate the relation between the characteristics of dynamics and the types of interactions.

16:40-17:00

O-31: Spin Nematic Order in Triangular Antiferromagnet

Hirokazu Tsunetsugu (Yukawa Institute for Theoretical Physics, Kyoto University)

We have investigated the possibility of spin nematic order in triangular antiferromagnet to explain spin liquid behavior in newly discovered $NiGa_2S_4$ compound. To this end, we employ a bilinear-biquadratic model with $S = 1$ and examine the effects of quantum fluctuations in the nematic phase with antiferromagnetic structure. Gapless excitations associated with the symmetry breaking lead to T^2 – behavior in specific heat and a finite value of spin susceptibility. These are consistent with experimental results observed in $NiGa_2S_4$. I will comment on a similar phase observed in a system with ring exchange interactions.

Poster Session

P-01. Orbital Physics in Pr-based f-electron Compounds

Tatsuya Kawae (Department of Applied Physics, Kyusyu University)

Recently, there has been a great deal of interest in *d* – and *f* – electron systems with an orbital degeneracy. Some Pr-based compounds have the quadrupolar moments of a non-Kramers Γ_3 doublet in the ground state, which enables us to study new phenomena arising from the fluctuation of the orbital moment, because the orbital degree of freedom is given by the quadrupolar moments in f-electron systems. We have studied $Pr_xLa_{1-x}Pb_3$ with the Γ_3 doublet in the ground state with changing Pr concentration. A variety of novel features such as non-Fermi liquid behavior are found at low temperatures, resulting from a long-range RKKY-type interaction between the quadrupolar moments and the conduction electrons.

P-02. Two-dimensional Electron Systems at Cleaved Semiconductor Surfaces and Observation of the Quantum Hall Effect

Toshimitsu Mochizuki, Yukihide Tsuji, Masayuki Hio, Tohru Okamoto
(Department of Physics, University of Tokyo)

Low-temperature in-plane magnetotransport measurements have been performed on adsorbate-induced electron systems formed at in situ cleaved surfaces of p-type InAs. The Ag-coverage dependence of the surface electron density strongly supports a simple model based on a surface donor level lying above the conduction-band minimum. The observations of the quantized Hall resistance and zero longitudinal resistivity demonstrate the perfect two dimensionality of the surface electron system. We believe that 2DESs formed at InAs surfaces will provide a fertile ground for the observation of novel transport phenomena. Research on spin-related transport in 2DESs with magnetic adsorbates is promising as well as investigations combined with scanning probe microscopy techniques.

P-03. Heat Capacity of ^{3}He Solid Films on Graphite in Magnetic Fields

Masashi Morishita (Department of Physics, University of Tsukuba)

Heat capacity of ^{3}He solid film adsorbed on a graphite surface was measured in some magnetic fields up to 400 Gauss. The results show large shifts to higher temperatures. The magnitude of the shift is about 0.2 mK at 100 Gauss. It is quite large compared with the magnetic energy of the ^{3}He nuclear magnetic moment in the magnetic field, which is about 0.01 mK at 100 Gauss. The effect of the magnetic field on the competition of the multiple spin exchange interactions, or the correlation of ^{3}He atoms will be discussed to explain the results.

P-04. Pulsed-NMR Measurements for Monolayer ^{3}He

K. Mukai, S. Murakawa, D. Tsuji, H. Kambara and Hiroshi Fukuyama
(Department of Physics, University of Tokyo)

Our recent cw-NMR and heat capacity measurements for the second layer ^{3}He adsorbed on graphite surface preplated with ^{4}He monolayer revealed that this simple 2D Fermion system has at least four distinct quantum phases with remarkably interesting properties depending on density. Pulsed-NMR measurements can give information on spin dynamics such as the spin-spin and spin-lattice relaxation times and diffusion constant of samples being not influenced by static field inhomogeneities. Here we present preliminary results of such measurements for 2D ^{3}He at densities near localization to the 4/7 commensurate phase. A new experimental setup specialized for the pulsed-NMR method below 1 mK will be also described.

P-05. Heat Capacity Measurements of a New Quantum Phase of Two-dimensional ^{3}He in High Magnetic Fields

Y. Matsumoto, K. Natsume, A. Yamaguchi, H. Ishimoto

(Institute for Solid State Physics, University of Tokyo)

Monolayer ^{3}He adsorbed on a graphite surface is an ideal two-dimensional Fermion system. Recent heat capacity measurements revealed the possible realization of a new quantum phase near the low density registered phase called the 4/7 phase. This phase is characterized by the anomalous coexistence of heat capacity peaks near 1 mK and a few tens of mK. The hole (zero-point vacancy) doped Mott localized phase and the phase separation in the momentum space are proposed as possible interpretations for these anomalies. To test these hypotheses, we start new heat capacity measurements in high magnetic fields. Here we present an experimental detail and test performance of a new apparatus.

P-06 Electronic States near Quantum Critical Point of Valence Transition

Shinji Watanabe and Masatoshi Imada (Institute for Solid State Physics, University of Tokyo)

Recently, Mott transition attracts much attention since new universality class has been identified as the marginal critical point. Valence transition provides a prototype of a metal-to-metal first-order transition with the critical end point (CEP), which seems to share common aspects of the Mott transition. To get insight into the mechanism of the CEP in the quantum degeneracy regime, we have studied the ground-state properties of the valence transition in a one-dimensional model using the DMRG method. We have constructed the ground-state phase diagram and have found that the superconducting correlation is enhanced near the quantum CEP. In the presentation, critical nature of the valence transition and effects of the valence instability on the superconductivity will be discussed in detail.

P-07. Mott Transition in the two-dimensional Hubbard Model with Geometrical Frustration

Takashi Koretsune (RIKEN)

We study the properties of Mott transition in the two-dimensional Hubbard model with geometrical frustration. Using exact diagonalization method and finite temperature Lanczos method, it is found that an expectation value of double occupancy has a discontinuity at finite U indicating the first order transition, though it highly depends on the boundary condition. The signal of the first order transition is also observed at finite temperatures.

P-08. Macrocoherence in Bilayer Quantum Hall States

A. Sawada, A. Fukuda, K. Iwata, T. Arai

(Research Center for Low Temperature and Materials Science, Kyoto University)

We expect many phenomena for interlayer macrocoherent states in bilayer quantum Hall systems at total Landau level filling factor $n = 1$. The ground state in these systems can be regarded as a superfluid of Chern-Simons composite bosons. We search novel phenomena by experiments of the transport, the magnetometry and the response for electromagnetic-waves. Many parameters are changed widely: electron-density, density-difference, tunneling-gap, layer-separation and tilt-angle of a sample to the magnetic field.

P-09. Mobility Measurements of Surface State Electrons on the Superfluid Helium Film

Hironori Kawashima, Yusuke Hayashi and Kimitoshi Kono
(RIKEN, Low Temperature Physics Laboratory)

The surface of superfluid He film is an ultra clean system, because there is no impurity and no defect. To study the surface of superfluid He, electrons on the He surface act as a good probe. When we measure the conductivity of electrons on the thin He film, we need the metal electrode which has the smooth surface and we have prepared such a substrate. We have measured the temperature dependence of the mobility of electrons on the He film which is adsorbed on the flat substrate and the substrate which has one-dimensional structure. The mobility of electrons on the film is smaller than the bulk one, because electrons are strongly coupled with the substrate.

P-10. Search for the Supersolid Phase in Bulk Solid ^{4}He

Motoshi Kondo, Shunichi Takada, Yoshiyuki Shibayama and Keiya Shirahama
(Department of Physics, Keio University)

Solid helium has been considered to have strong quantum properties because of its light mass and weak atomic interaction. The large zero-point motion results in the frequent atomic exchanges, and hence a superflow may occur even in solid ^{4}He. In recent tortional oscillator experiments by Kim and Chan, nonclassical rotational inertia (NCRI) of solid ^{4}He has been observed in a porous Vycor glass and a bulk annular channel. The observation of the NCRI strongly suggests the existence of superflow in solid ^{4}He. In order to study the possible supersolid phase, we make a torsional oscillator experiment for cylindrical solid ^{4}He samples. Some preliminary results will be presented.

P-11. Development of a Low Temperature Scanning Probe Microscopy

Kohta Saitoh, Yoshiyuki Shibayama and Keiya Shirahama
(Department of Physics, Keio University)

Scanning Probe Microscopy (SPM) has broad utility in studying surfaces on nanoscale, and has been actually applied to a great number of condensed matter studies. However, SPM has been hardly operated at low temperatures. Low temperature SPM will provide us with a powerful and microscopic means for studying quantum phenomena.

We develop a SPM working at very low temperatures (10mK). Our SPM is based on Frequency Modulation Atomic Force Microscopy (FM-AFM). In FM-AFM, an oscillator circuit drives a high Q cantilever at its resonance frequency. The frequency shift that arises from tip-sample interaction is used as the probing signal.

As Q tends to be high at low temperature, FM detection is quite suitable for low temperatures, compared to other conventional AFM techniques. We employ a quartz tuning fork as a cantilever. It is also suitable for low temperature use, because of negligible heat production in operation.

We will present the basic concept and structure of our SPM, and discuss some problems.

P-12. Measurements of Freezing Pressure of Supercooled Liquid Hydrogen Confined in Nano-porous Glass

Yosuke Ishii, Yoshiyuki Shibayama and Keiya Shirahama
(Department of Physics, Keio University)

Hydrogen (H_2) is the lightest molecule in nature. If its solidification is suppressed, strong quantum effects such as Bose-Einstein condensation (BEC) and superfluidity are expected at low temperatures. Several works revealed that supercooling of hydrogen was possible down to 9 - 11 K by confining it within a Vycor glass, which has nanopores of 6-8 nm in diameter, but suggested no indication of such quantum effects. In order to achieve a larger amount of supercooling and search for a quantum liquid state, we perform pressure measurements of hydrogen confined in porous Gelsil glass, which has nanopores of 2.5 nm in diameter. We explore the $P - T$ phase diagram (melting curve), which may indicate quantum effects. Some preliminary results will be presented.

P-13. Monte Carlo Simulation of ^{4}He in a Small Pore Geometry

Takeo Takagi (Depertment of Applied Physics, Fukui University)

We confined ^{4}He particles in a small pore geometry. The radii of the pore were a few times of the particle diameter. Thermodynamical quantities were calculated by a path integral Monte Carlo simulation. The calculation was carried out for Bose statistics and Maxwell-Boltzmann statistics. Superfluidity of the system is discriminated by a coherence of the particle which is measured by the world line connectivity. Difference of the statistics was found for almost every pore radius, but the superfluidity was observed in a larger size of pore than that of critical pore radius R_c.

P-14. Heat Capacity Measurement of ^{4}He Confined in a Nano Porous Material

K. Yamamoto, Y. Sogabe, Y. Shibayama, K. Shirahama (Department of Physics, Keio University)

Confinement of ^{4}He in a porous material suppresses superfluidity. In our previous torsional oscillator study, we found that the superfluidity of ^{4}He in a porous Gelsil glass which has nanopores of 2.5 nm in diameter was drastically suppressed by pressurization and the transition temperature approaches to 0 K at a pressure P ~ 3.4 MPa. In addition, the freezing curve was elevated about 1MPa from bulk freezing pressure. Above two experiments indicate existence of the nonsuperfluid phase, which has small entropy, next to the solid phase. In order reveal the nature of the nonsuperfluid phase, we measure heat capacity by means of an AC method. Preliminary results will be presented.

P-15. Interfacial Friction of ^{4}He Films

Nariko Hosomi, Ayano Tanabe, Kiyokazu Hasegawa, Junko Taniguchi, Masaru Suzuki
(Dept. of Applied Physics and Chemistry, University of Electro-Communications)

We have studied the interfacial friction of ^{4}He films adsorbed on several substrates using the quartz-crystal microbalance technique. For ^{4}He on Grafoil, this friction was measured for several amplitudes, ranging from 0.1 to 1 nm of the 5 MHz. Above around the first layer completion, the decrease in this friction was clearly observed for a large amplitude below a certain temperature T_S, and T_S decreases abruptly at around the second layer completion. The decrease in this friction was also observed for ^{4}He films on Grafoil preplated with one-atomic layer of Kr (Kr/Gr) and on porous gold.

P-16. Ultrasonic Study for Superfluidity of ^{4}He Filled in Porous Media

T. Kobayashi, S. Fukazawa, J. Taniguchi, M. Suzuki, K. Shirahama[A]
(Dept. of Applied Physics and Chemistry, University of Electro-Communications
[A]Dept. of Physics, Keio University)

Superfluidity of ^{4}He is an interesting topic of low temperature physics. Recently, Kim and Chan reported a supersolid state of solid ^{4}He On the other hand, Yamamoto et al. observed a large suppression of superfluidity in Gelsil glass. These phenomena will open up a new field in superfluid physics. Thus motivated, we have started ultrasonic measurements for a porous Vycor glass filled with solid ^{4}He, and for a Gelsil glass filled with liquid ^{4}He. We report the pressure and temperature dependence of the sound velocity for these systems.

P-17. Heat-capacity Study of Quantum Helium Fluid Adsorbed on One-dimensional Nanopores of FSM-16

Yuki Matsushita, Ryo Toda, Junko Taniguchi [A], Mitsunori Hieda, Taku Matsushita, and Nobuo Wada (Nagoya University, [A] University of Electro-Communications)

We have studied ^{3}He and ^{4}He adsorbed on one-dimensional (1D) nanopores with various diameters 1.8-2.8 nm. In the pores, we found that quantum helium tube of fluid layer is formed on about one atomic solid layer. We consider one-dimensionality condition for the ^{3}He and ^{4}He fluid tubes. Since motions in the cross-section of the fluid tubes are likely to have discrete energy levels, the fluid tubes would behave as 1D fluids at low temperatures, typically below 0.1 times a gap temperature between the lowest two of these levels. The experimental results of the heat capacities are discussed.

P-18. Possible Quantum Clusters of Helium in Cages of NH_4-Y Zeolite

Hiroyuki Shutto, Yuki Matsushita, Ryo Toda, Mitsunori Hieda, Taku Matsushita, and Nobuo Wada (Department of Physics, Nagoya University)

We have measured heat capacities of ^{3}He and ^{4}He adsorbed on NH_4-Y zeolite which has cages of 1.3 nm in diameter connected through apertures of about 0.8 nm in diameter. Preplating with solid monolayer of helium, an isolated quantum cluster of a few atoms is expected to be formed in each cage. We report our recent experimental results of ^{4}He and ^{3}He adsorbed on NH_4-Y zeolite.

P-19. Quantum Ground States Realized in Low-dimensional Heisenberg Organic Magnets

Kengo Shimizu, Tomotaka Gotohda, Yoshikazu Kugimiya, Nobuko Hamaguchi, Taku Matsushita, and Nobuo Wada (Department of Physics, Nagoya University)

Low-dimensional (low-D) Heisenberg spin systems have been attracting much attention since they are expected to have quantum ground states. Here we show experimental results on several organic magnets with the low-D Heisenberg system. *m*-MPYNN・BF_4 is a two-dimensional (2D) Kagome lattice of S = 1 dimers of two radical spins. It has a nonmagnetic ground state with a spin gap of 0.2 K in zero field. Magnetization curve show plateaus at 1/2 and 3/4 of the saturation magnetization. We also report results of β – BBDTA・$GaBr_4$ that has ferromagnetic and antiferromagnetic one-dimensional (1D) Heisenberg chains, and F_5PNN that has bond-alternating antiferromagnetic chains.

P-20. Superfluidity and Heat Capacities of ^{4}He Adsorbed on Three-Dimensional Nanopores of HMM-2

Ryo Toda, Yuki Matsushita, Mitsunori Hieda, Taku Matsushita, and Nobuo Wada (Department of Physics, Nagoya University)

We have studied ^{4}He quantum fluid film adsorbed on HMM-2 which has ordered three-dimensional (3D) network of 2.7 nm pores. In simultaneous measurements of heat capacity and torsional oscillator, we observed a sharp peak of the heat capacity just at superfluid onset temperature within experimental error of 10 mK at the onset temperature 300 mK. This result suggests that the 3D superfluid transition occurs in ^{4}He film adsorbed on HMM-2. Coverage (density) dependence of the onset temperature is compared with these of Bose glass and of BEC temperature of 3D ideal Bose gas. Low temperature heat capacity and superfluid density is also discussed in terms of phonon elementary excitations.

P-21. Frequency Dependence of Superfluidity in Thin ^{4}He Films on Planar Surfaces

T.Kato, M.Hieda, T.Matsushita, and N.Wada (Department of Physics, Nagoya University)

The superfluid phase transition in thin ^{4}He films on planar surfaces is generally acknowledged to be a realization of the Kosterlitz-Thouless (KT) two-dimensional (2D) phase transition. According to the dynamic KT theory, observation of the superfluidity on an oscillating substrate depends on the measuring frequency. We undertook a systematical study of the frequency dependence for the superfluid density and the dissipation of ^{4}He film on planar surfaces using a quartz crystal microbalance (QCM) technique in the wide range of the resonant frequency from 12 MHz to 180 MHz. In the preliminary experiment, we observed increase in the transition temperature and broadening of the transition with increasing the frequency. This frequency dependence qualitatively agrees with the dynamic KT theory.

P-22. Itinerant-localized Duality of a Strongly-correlated Superfluid Bose Gas in an Optical Lattice

Y. Ohashi, M. Kitaura, and H. Matsumoto (Institute of Physics, University of Tsukuba)

We discuss superfluid properties near the Mott insulator transition of a strongly-correlated Bose gas in an optical lattice. In the Mott phase, the excitation spectrum has a finite energy gap, reflecting the localized character of atoms. In the superfluid phase, we show that the excitation spectrum has an itinerant-localized dual structure, where the gapless Bogoliubov mode (which describes the itinerant character of superfluid atoms) and a band with a finite energy gap coexist. We also discuss how this dual band structure can be observed by using the rf – tunneling current spectroscopy.

P-23. Pattern Formation of Spin-Polarized Fermions in a Fast Rotating Boson-Fermion Mixture

Rina Kanamoto and Makoto Tsubota (Department of Physics, Osaka City University)

Ultracold atomic gases provide the ideal testing ground for the underlying quantum physics of matters. One of eccentric phenomena in a condensed matter is the quantum Hall effect (QHE), and the interpretations of this phenomenon have been elaborated in a lot of fields. The neutral atoms under a fast rotation exhibit the QHE regardless of their statistics as well as charged particles in the strong magnetic field. In this poster, we consider the two-dimensional neutral gas of boson-fermion mixture under rotation, and discuss the fermi-atom analogue of the quantum dot in the QH regime.

P-24. Dynamics of ^{87}Rb Spin-2 Bose-Einstein Condensates

Takeshi Kuwamoto and Takuya Hirano (Department of Physics, Gakushuin University)

We experimentally studied the spin-dependent collision dynamics of ^{87}Rb spin-2 Bose-Einstein condensates confined in an optical trap. The condensed atoms were initially populated in the ($F = 2$, $m_F = 0$) state, and their time evolutions were measured in the presence of external magnetic field ranging from 0.1 to 3.0 G. Spin mixing in the $F = 2$ manifold developed dramatically for the first few tens of milliseconds, and the oscillations in the population distribution between different m_F components were observed over a limited range of magnetic field. The antiferromagnetic property of this system was deduced from the magnetic-field dependence on the evolution of relative populations for each m_F component.

P-25. Possible Supersolid Phase in Bose-Einstein Condensate with Optical-lattice Potential

Xiao Hu and Masanori Kohno (National Institute for Materials Science)

Bose-Einstein condensation (BEC) has been achieved for ultracold atoms. Ramping an optical-lattice potential, a transition of the BEC from superfluid (SF) phase to Mott insulator (MI) phase was observed experimentally. These progresses raise considerable interest for searching the supersolid (SS), a novel intermediate phase between SF and MI. Using the density-functional theory (DFT) for crystallization we find that in two dimensions a smectic phase, which shows the SS property, can be stabilized by a periodic one-dimensional potential beyond a critical strength. We are trying to compose phase diagrams by DFT as well as quantum Monte Carlo simulations.

P-26. Dynamics of Two-component Bose-Einstein Condensates in an Optical Trap

Kohei Hamazaki, Masafumi Iwata, Takeshi Kuwamoto and Takuya Hirano (Department of Physics, Gakushuin University)

We study the dynamics of two-component ^{87}Rb (F = 2, m_F = -2) and (F = 1, m_F = -1) Bose-Einstein condensates (BEC) in an optical trap. Because we can simultaneously confine BEC in various hyperfine states in the trap, atoms in the trap have internal degrees of freedom. In our experiment, we first prepared F = 2 BEC and then transferred its atomic state to F = 1 by applying a microwave field. We could control the relative population of atoms with the microwave power. We observed that two-component BEC tend to spatially separate each other in the trap, and show center of mass motions.

P-27. Einstein-de Haas Effect in Dipolar Bose-Einstein Condensates

Yuki Kawaguchi, Hiroki Saito, Masahito Ueda (Department of Physics, Tokyo Institute of Technology)

The magnetic dipole-dipole interaction couples the spin and orbital angular momenta so that spin relaxation causes the system to rotate mechanically (the “Einstein – de Haas effect") or, conversely, a solid-body rotation of the system leads to its magnetization (the ”Barnett effect"). We show that these effects also occur in a dipolar Bose-Einstein condensate in which atoms undergo scalar, spinor, and dipolar interactions. General properties of the order parameter for a dipolar spinor multicomponent Bose-Einstein condensate is discussed based on symmetries of the interactions, and an initially spin-polarized dipolar condensate is shown to dynamically generate a new type of non-singular vortex via spin-orbit interactions. We also discuss the effect of the external magnetic field and that of the trap geometry on the properties of the condensate.

P-28. Topological Vortex Nucleation in Bose-Einstein Condensates

Hayato Usuda, Yuki Nara, Takeshi Kuwamoto, and Takuya Hirano (Department of Physics, Gakushuin University)

Vortices were imprinted in Bose-Einstein condensates by manipulating the phases of the condensates. ^{87}Rb condensates held in Ioffe-Pritchard magnetic trap were transformed to a state with the quantized circulation of the winding number 4 by adiabatically inverting the magnetic bias field along the trap axis. We observed condensates using absorbed imaging after ballistic expansion and identified the vortices by distinct central density depletion along the trap axis. Furthermore, we imaged a condensate from two directions along the trap axis and perpendicular direction to the axis in order to verify the existence of the vortex line. We have been trying to nucleate vortices inside two-component (F = 1 and F = 2) ^{87}Rb condensates.

P-29. Spin Current in p-wave Superconducting Rings

Yasuhiro Asano (Department of Applied Physics , Hokkaido University)

A formula of spin currents in mesoscopic superconductors is derived from the mean-field theory of superconductivity. Spin flow is generated by spatial gradient of d – vector which represents a spin state of spin-triplet superconductors. We discuss a possibility of circulating spin currents in isolated p – wave superconducting rings at the zero magnetic field. The direction of spin currents depends on topological numbers which characterize spatial configurations of d – vector on the ring.

P-30. Josephson Current between p-wave Superconductors

T. Yokoyama (Department of Applied Physics, Nagoya University)

Josephson current in p – wave superconductor / diffusive normal metal / p – wave superconductor junctions is studied. It is shown that the magnitude of the Josephson current strongly depends on the lobe directions of the p – wave pair potentials and the resulting magnitude of the Josephson current is large compared to that in the s – wave superconducting junctions due to the formation of the resonant states peculiar to p – wave superconductors.

P-31.. Texture of Superconducting Order Parameter Expected in the FFLO State of $CeCoIn_5$

K. Kumagai (Department of Physics, Hokkaido University)

We present ^{115}In-NMR studies of newly discovered heavy-fermion superconductor, $CeCoIn_5$, which is believed to host superconductivity with ultra-clean limit and Pauli paramagnetic limit. ^{115}In-NMR spectra exhibit a dramatic change below $T^*(H)$ in the vicinity of upper critical field. We simulate the spectra by a model with a spatially-modulated superconducting energy gap, and are able to establish a clear evidence of the texture structure of the SC parameter at high field and low temperatures, as expected in the Fulde-Ferrell-Larkin-Ovchinikov (FFLO) state.

K. Kakuyanagi, *et al*., Phys. Rev. Lett. **94**, 047602 (2005).

P-32. Microscopic Theory on the Multi-component Superconducting Order Parameter in Sr_2RuO_4 and $Na_xCoO_2 \cdot yH_2O$

Yoichi Yanase (Department of Physics, University of Tokyo)

We have developed a microscopic theory on the multi-component order parameter in spin triplet superconductors, Sr_2RuO_4 and $Na_xCoO_2 \cdot yH_2O$. We have analyzed multi-orbital Hubbard models including the spin-orbit coupling and found some exact results. This is the first microscopic theory on the multi-component order parameter in metal superconductors. We show that the pinning of d – vector is much smaller in Sr_2RuO_4 than $Na_xCoO_2 \cdot yH_2O$ and that is not directly related to the anisotropy of magnetic susceptibility. We have derived an effective BCS model and Ginzburg-Landau model from the microscopic theory and determined the phase diagram in the magnetic field. The comparison between our theoretical predictions and experimental results is discussed.

P-33. Transport through Quantum Dots in the Kondo Regime: Normal and Superconducting Cases

Akira Oguri (Department of Material Science, Osaka City University)

We study the transport properties of quantum dots in two different situations, where both of the attached reservoirs on the left and right are in the I) normal and II) superconducting (SC) states, using the numerical renormalization group (NRG) approach. At low temperatures, the interplay between the Kondo and Mott-Hubbard insulating behavior affects the conductance through a one-dimensional chain of quantum dots connected to normal leads. In the SC case, a quantum phase transition (QPT) between nonmagnetic and magnetic ground states occurs depending on the values of the Kondo temperature and SC energy gap. The Josephson current changes the direction discontinuously at the critical point. We will discuss these features in detail.

P-34. Superconductivity and a Mott Transition in a Hubbard Model on an Anisotropic Triangular Lattice

TsutomuWatanabe [A], Hisatoshi Yokoyama [B], Yukio Tanaka [A] and Jun-ichiro Inoue [A]
([A] Department of Applied Physics, Nagoya University
[B] Department of Physics, Tohoku University)

With a mind to a Mott transition and superconductivity (SC) arising in κ-(BEDT-TTF)$_2$X, we study a half-filled-band Hubbard model on an anisotropic triangular lattice (t in two bond directions and t' in the other). Using a variational Monte Carlo method, we find that a first order Mott transition takes place at $U = U_c$ approximately of the band width. For a moderate frustration ($t'/t = 0.4$), the d-wave superconducting correlation is sizably enhanced just under U_c, whereas for a strong frustration ($t'/t = 0.8$), it is hardly enhanced for any value of U/t. Since the behavior is closely connected to that of the spin structure factor $S(\pi, \pi)$, the SC in this model must be induced by the antiferromagnetic correlation.

P-35. Superconductivity and Mott Transition in a two-dimensional Hubbard Model at Half Filling

Hisatoshi Yokoyama (Department of Physics, Tohoku University)

Recently, superconductivity at 25K was found in thin film samples of parent (non-doped) compounds of electron-doped cuprate superconductors. With this phenomenon in mind, we study a two-dimensional half-filled-band Hubbard ($t - t' - U$) model using an optimization variational Monte Carlo method, in which doublon – holon correlation factors are considered. We have found that a Mott transition takes place at around the correlation strength U/t of the band width. Slightly below this value of U/t and for a moderate frustration ($0.25 < t'/t < 0.35$), robust superconductivity with the $d_{x^2-y^2}$ symmetry is found.

P-36. The Low Temperature Magnetic Properties of Unconventional Superconductor $PrOs_4Sb_{12}$

Yoshitomo Karaki
(Institute for Solid State Physics, University of Tokyo)

The magnetization and susceptibility of Unconventional superconductor $PrOs_4Sb_{12}$ have been measured at temperatures down to 20mK using a DC SQUID. The magnetization hysteresis loops are observed under cycling field of 700 Oe. An irreproducibility of the hysteresis loops appears below 150 mK and becomes apparent as decreasing temperature. As proposed by Sigrist and Agterberg, the irreproducibility is attributable to an anomalous pinning mechanism of vortices in a superconductor with broken time-reversal symmetry (TRS). Zero field magnetization measurements have been performed to detect intrinsic spontaneous magnetization which is expected of TRS breaking superconductors.

P-37. Superconducting States in a Two-orbital Hubbard Model on a Triangular Lattice

Kenji Kobayashi (Faculty of Engineering, Chiba Institute of Technology)

As a model of the novel superconductor $Na_xCoO_2 \cdot yH_2O$, we study a triangular Hubbard model with doubly degenerate orbitals, based on variational Monte Carlo calculations. Using the Gutzwiller-projected BCS wave function extended for the two-orbital model, we determine the stable region of superconductivity and its pairing symmetry for various values of interaction strength and electron density. It is found that, among various pairing symmetries, $d_{x^2-y^2}$ and $d_x + id_y$ wave superconducting states are appreciably stabilized when the isolated Fermi surface overlaps the van Hove singularity points with large Coulomb interactions. This superconductivity is mainly induced by the potential energy gain due to the nearest-neighbor antiferromagnetic spin correlations. The possibility of triplet pairing is very slight for the present parameters.

P-38. Superconductivity of Sr_2RuO_4-$Sr_3Ru_2O_7$ Eutectic

S. Fusanobori [A], S. Kittaka [A], H. Yaguchi [A], S. Yonezawa [A], Y. Maeno [A, B], R. Fittipaldi [A, B, C], and A. Vecchione [A, B, C] (Dept. Phys., Kyoto Univ. [A], IIC, Kyoto Univ. [B], Univ. of Salerno, Italy [C])

We have succeeded in synthesizing Sr_2RuO_4-$Sr_3Ru_2O_7$ eutectic by a floating zone method. AC susceptibility measurements revealed, in addition to the superconducting transition in bulk Sr_2RuO_4 (1.5 K), two other superconducting transitions at about 1 K and 0.8 K. These two transitions occur in the $Sr_3Ru_2O_7$ part and are very sensitive to AC and / or DC magnetic fields smaller than a few Oersteds. The apparent volume fractions associated with these superconducting transitions are substantially large. Possibilities of a network of proximity effects between Sr_2RuO_4 grains embedded in $Sr_3Ru_2O_7$ will be discussed. We will also present results of resistive measurements on Sr_2RuO_4-$Sr_3Ru_2O_7$ eutectic.

P-39. Triplet Superconductivity Induced by Short-Range Ferromagnetic Correlations Due to the Coulomb Repulsion at Oxygen Site in Sr_2RuO_4

Kengo Hoshihara (Department of Materials Engineering Science , Osaka University)

A microscopic origin of the triplet superconductivity in Sr_2RuO_4 is discussed paying attention to a role of Coulomb repulsion at O site (U_{pp}). We consider that the Hubbard model with only on-site repulsion at Ru site (U_{dd}), seems too stoical to discuss the superconductivity because of a specialty of this system. Considering U_{dd} and U_{pp} within the perturbation theory, we show that the short-range ferromagnetic correlations between the "d - electrons" at adjacent Ru sites are induced, which was measured quite recently by the inelastic neutron scattering experiment, and that the Cooper pairing with $(\sin p_x \pm i \sin p_y)$ symmetry is promoted on the γ -band.

P-40. Magnetization Process in a Chiral p – wave Superconductor with Multi-domains

M. Ichioka, Y. Matsunaga, K. Machida (Department of Physics, Okayama University)

A simulation study for the magnetization process is performed for the multi-domain state in a chiral p – wave superconductor, using the time-dependent Ginzburg-Landau theory. The external field penetrates inside as core-less vortices through the domain wall, forming the vortex sheet structure. We find that, with increasing magnetic fields, the domain walls move so that the unstable domains shrink to vanish. Therefore, the single domain structure is realized at higher fields.

P-41. Electronic Structure of Vortex State in a FFLO Superconductor

M. Ichioka, H. Adachi, T. Mizushima, K. Machida (Department of Physics, Okayama University)

Spatial structure of the vortex state in a Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) superconductor is microscopically investigated by the quasiclassical Eilenberger theory. We calculate the spatial structure of the pair potential, paramagnetic magnetization (i.e., Knight shift in a magnetic field) and electronic states, including paramagnetic depairing effect in addition to the orbital depairing effect. Topologies of 2π phase winding at the vortex line and π phase shift at the FFLO nodal plane affect the distribution of paramagnetic magnetization and low energy electronic states. We also discuss the NMR resonance line shape observed in the high field phase of $CeCoIn_5$.

P-42. Ring-exchange Mechanism for Triplet Superconductivity in a Two-chain Hubbard Model

Yukinori Ohta (Department of Physics, Chiba University)

The density-matrix renormalization group method is used to study the ground state of the two-chain zigzag-bond Hubbard model at quarter filling. We show that, with a proper choice of the signs of hopping integrals, the ring exchange mechanism yields ferromagnetic spin correlations between interchain neighboring sites, and produces the attractive interaction between electrons as well as the long-range pair correlations in the spin-triplet channel, thereby leading the system to triplet superconductivity. We argue that this novel mechanism may have possible relevance to observed superconductivity in Bechgaard salts.

Reference: Y. Ohta et al. PRB **72**, 012503 (2005).

P-43. Formation of non-unitary state near the upper-critical field of Sr_2RuO_4

Masafumi Udagawa (Department of Physics, University of Tokyo)

We have studied the superconducting state of Sr_2RuO_4 under a magnetic field parallel to the superconducting plane. On the basis of quasiclassical analysis, we show that non-unitary $k_y(\hat{z}-i\alpha\hat{y})$ state is formed right at H_{c2} as a result of the competition between spin-orbit interaction and Zeeman energy. As a magnetic field is lowered, this state changes to unitary $k_y\hat{z}$ state. On the basis of this crossover, we address the origin of the observed double peaks of specific heat and the disappearance of the double peaks at low fields. We have also investigated the position of the phase transition line proposed by Agterberg.

P-44. Pressure and Magnetic-field Induced Novel Quantum Phenomena in Single-layered Ruthenates

Fumihiko Nakamura, Masakazu Ito and Takashi Suzuki (ADSM, Hiroshima University)

There has been growing interest in novel quantum phenomena induced by multiple extreme conditions. In particular, pressure is a suitable technique to tune the internal parameters of super clean systems without introducing disorder. In single-layered ruthenates, especially Ca_2RuO_4, we have reported that pressure induces a wide variety of attractive phenomena such as a Mott transition, an itinerant ferromagnetism, a large magneto resistance effect and a FM quantum critical-point. We thus have strong interests in higher-pressure measurements as a crucial test of the connection between the triplet superconductivity of Sr_2RuO_4 and the ferromagnetism of metallic Ca_2RuO_4. Moreover, new field-induced phases are fully expected in the superconductivity in Sr_2RuO_4 and pressurized Ca_2RuO_4.

P-45. Interface Superconductivity (3-K Phase) in Sr_2RuO_4-Ru under Uniaxial Pressure

Hiroshi Yaguchi [A], Shunichiro Kittaka [A], Keiichi Takizawa [A] and Yoshiteru Maeno [A,B]

([A]Department of Physics, Kyoto University, [B]International Innovation Center, Kyoto University)

The eutectic system Sr_2RuO_4-Ru is known to show surface superconductivity with an enhanced transition temperature of about 3 K, called the 3-K phase, while that of Sr_2RuO_4 is 1.5 K. Although its mechanism still remains unknown, strain at interfaces between Sr_2RuO_4 and Ru might play an important role in the enhancement of T_c. We have made magnetization measurements under uniaxial pressure using a commercial SQUID magnetometer. We have found that the transition temperature and the apparent volume fraction associated with the 3-K phase are greatly enhanced for pressures both parallel and perpendicular to the c-axis. Possible implications of such enhancement will be discussed.

P-46. Neutron scattering studies on Sr_2RuO_4

Hazuki Furukawa (Department of Physics, Ochanomizu University)

Sr_2RuO_4 is a spin triplet superconductor discovered in 1994 [1]. Neutron scattering experiments, however, found strong incommensurate fluctuations appear at around (1/3 1/3 0) [2]. Some theoretical groups predicted that if such an incommensurate fluctuation possesses the c – axis anisotropy, spin triplet superconductivity could be stabilized. Our inelastic neutron scattering measurements succeeded in demonstrating the c – axis anisotropy of the fluctuation with anisotropic factor of ~ 4 [3]. In the workshop, I will explain ongoing project, too.

1.Y. Maeno et al., Nature **372**, 532 (1994).

2. Y. Sidis et al., Phys. Rev. Lett. **83**, 3320 (1999).

3. Nagata et al. Phys. Rev. B **69**, 174501 (2004).

P-47. Superclean *d* – wave $YBa_2Cu_4O_8$ single crystal embedded in conventional superconductor to design a novel physical system

Takekazu Ishida, Shuichi Kawamata, Kazuo Sato, Tsutomu Yotsuya, Takato Machi

(Department of Physics and Electronics, Osaka Prefecture University)

So far, we carried out the following researches by using superclean $YBa_2Cu_4O_8$ single crystals; vortex phase diagram in H // c – axis as well as $H \perp c$-axis, superconducting anisotropy, a novel phase diagram of hidden competing orders in H // a – axis. Thanks to super cleaness, the phase diagram revealed a field-induced hidden order in the underdoped state. On the basis of the preceding works, we plan to fabricated an unconventional d – wave dots ($YBa_2Cu_4O_8$ single crystals) embedded in a conventional Nb or Pb matrix with the aid of nanofabrication instruments. Because of internal freedom of the d – wave order parameter, we expect the spontaneous generation of half vortices. This can be used to construct a novel physical system.

P-48. Emergence of FFLO Modulation in Surface Regions of Trapped Fermionic Superfluid with Asymmetric Spin Populations

Takeshi Mizushima (Department of Physics, Okayama University)

We discuss on the possibility of the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state in a trapped superfluid with imbalanced spin populations. By solving the Bogoliubov-de Gennes equation, it is found that while the BCS state is still robust against the increase of the population difference, its pairing state immediately becomes unstable in the vicinity of the surface regions and FFLO modulation emerges there. In addition, we will comment on recent experiments in the vicinity of the Pauli limit of superfluidity.

P-49. Measurement of the ^{101}Ru-Knight Shift of Superconducting Sr_2RuO_4 in a Small Magnetic Field

H. Murakawa[A], K. Ishida[A], K. Kitagawa[A], Z. Q. Mao[A], and Y. Maeno[A,B]

(Dept. Phys., Kyoto Univ.[A], IIC, Kyoto Univ.[B])

We have measured the ^{101}Ru Knight shift under small magnetic fields in order to determine the direction of the $\boldsymbol{d}$ – vector in a zero field. Since the nuclear gyromagnetic ratio of Ru is very small ($\gamma_n/2\pi$ ~0.2 MHz/kOe for ^{99}Ru and ^{101}Ru) and the natural abundance of NMR isotopes is low (12,7 % for ^{99}Ru and 17.1 % for ^{101}Ru), we used the ^{101}Ru-NQR transition between $I_z = \pm 1/2 \leftrightarrow \pm 3/2$ to observe the Ru signal in a small magnetic field.

In the spin-triplet superconductor, when a magnetic field is applied parallel to the $\boldsymbol{d}$ – vector direction and the Zeeman energy by the field is smaller than the spin-orbit coupling energy to lock the $\boldsymbol{d}$ – vector, a decrease of the Knight shift is expected in the superconducting state. In the previous measurement, the Knight shift is unchanged down to 200 Oe in the field parallel to the *c* axis [1]. We will present a new Knight-shift measurement in a small field perpendicular to the *c* axis, in which the field direction is precisely tuned by a rotator.

[1] H. Murakawa *et al.* Phys. Rev. Lett. **93**, 167004 (2004).

P-50. Detection of Adsorbed Two-Dimensional Atomic Hydrogen Gas by Helium Surface State Electrons

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For the purpose of detecting two-dimensional superfluidity of cold atomic hydrogen gas (2D-H) adsorbed on liquid helium surface, we are developing a new technique to sense the state of 2D-H. We use surface state electrons (SSE) as a probe. An applied magnetic field perpendicular to the surface suppresses reaction rates of hydrogen recombination and electron attachment. We are measuring the edge magnetoplasmon resonance spectrum of SSE. We report the latest experimental result that shows a broadening of the line width under the influence of 2D-H.

P-51. Surface Andreev Bound States of the Superfluid ^{3}He A and B Phases

Y. Wada, R. Nishida, M. Saitoh, Y. Aoki, R. Nomura and Y. Okuda

(Department of Physics, Tokyo Institute of Technology)

By the measurements of the transverse acoustic impedance *Z* using a AC-cut quartz transducer, we investigated superfluid ^{3}He near a wall in order to study the effect of quasi-particle scattering off a diffusive surface. The measured temperature dependences of *Z* in the A and B phases were well explained by considering surface Andreev bound states and we had the information of surface density of states (SDOS) of superfluid ^{3}He for the first time. Flat and gapless SDOS was confirmed in the A phase. SDOS in the B phase had an additional gap between the upper energy edge of the surface Andreev bound states band and the bulk energy gap.

P-52. Motion of a Sound-induced Bubble in ^{3}He-^{4}He Liquid Mixtures

H. Abe, Y. Saitoh, T. Ueda, R. Nomura and Y. Okuda

(Department of Physics, Tokyo Institute of Technology)

When an acoustic wave pulse of 1 msec duration was applied to the ^{3}He dilute phase in phase-separated ^{3}He-^{4}He liquid mixtures, a single bubble was nucleated on an active area of the piezoelectric transducer. The motion of the bubble was observed by using a high-speed camera. The nucleated bubble continued expanding after the pulse was turned off and reached a maximum radius which depended on the applied acoustic power. Subsequently, the bubble detached from the transducer with shrinking and went upward. Then we found that a liquid jet penetrated through the bubble and produced a vortex ring during the collapse. This is similar to a process in water which produces a hollow vortex ring.

P-53. Dynamics of Magnetically Induced Superflow in Spin-Polarized ^{3}He-A_1

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Super spin and mass currents are induced in superfluid ^{3}He A_1 phase in high magnetic field by applying magnetic field gradients along superleak channels connecting a reservoir and a small chamber. The induced magnetic fountain pressure is related to effects involving critical velocity, spin relaxation time, spin density oscillation, and A_1 / A_2 superfluid interface. The observed relaxation of fountain pressure is directly related to the spin relaxation. Newly designed apparatus has been constructed to carry out extensive measurements. Recent results will be reported on the dependences on temperature, pressure, applied magnetic field.

P-54. Investigation of New Phases in Submicron Superfluid ^{3}He Film by Inter-digitated Capacitors

Masamichi Saitoh and Kimitoshi Kono

(Low Temp. Phys. Lab., RIKEN)

Superfluid ^{3}He film is the most advantageous super-clean material to understand boundary effects of unconventional superfluid/superconductor systems. In the thickness region of several hundreds nano meters, thickness induced A-B phase transition and stripe phase were predicted, as novel features of superfluid ^{3}He film. Inter-digitated capacitor is a powerful tool to investigate these new phases because of its high controllability and sensitivity of submicron film. By using this device, we will try to observe these phases in a magnetic field dependence of critical current.

P-55. Study of Two-dimensional Spin Polarized Atomic Hydrogen Using Heterodyne ESR Technique

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[B]Department of Physics, Kyoto University)

We have studied spin-polarized atomic hydrogen in high magnetic fields which are adsorbed on liquid helium surface below 1K. We prepared a cold spot in the sample cell with a constant input flux of atomic hydrogen and cooled absorbed hydrogen on the cold spot much below 100 mK. Our goal is to achieve the Kosterlitz – Thouless transition of 2-D hydrogen gas. We used a very high resolution 128 GHz ESR to directly detect 2-D atomic hydrogen. So far ESR signal of 2-D atomic hydrogen have not been detected because of poor field homogeneity and ESR sensitivity. We will report the development of a ultra-sensitive heterodyne ESR system with a SIS mixer, using a HEMT amplifier as a local frequency amplifier at low temperature to improve the ESR sensitivity.

P-56. Rotating Nuclear Demagnetization Cryostat for Homogeneous and High Magnetic Field Experiments

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[B]Graduate School of Science, Kyoto University,

[C]School of Health Sciences, Faculty of Medicine, Kyoto University)

We are now constructing a new rotating nuclear demagnetization cryostat. It has two magnets, one is for demagnetization and the other is a high homogeneous and high field superconducting magnet up to 8 T. Rotating parts are constructed with a magnetic fluid sealing and an air bearing. Using the new cryostat, we are planning MRI experiments for direct measurement of vortices of the superfluid A phase, which needs high homogeneous magnetic field. Also experiments on A_1-phase vortices are planned in high magnetic field.

P-57. The Study of Superfluid ^{3}He in Aerogel using Fourth Sound Resonance

K. Obara, Y. Nago, H. Yano, O. Ishikawa, T. Hata

(Department of Physics, Osaka City University)

The resonance frequency and the quality factor of superfluid fourth sound have been measured in the aerogel whose internal structure is quasi-periodic. The superfluid fraction and superfluid transition temperature shows the strong suppression compared with the pure liquid. The phase diagram is in good agreement with the inhomogeneous isotropic scattering model (IISM). We will discuss the relation between the model and the spatial periodicity in the aerogel. And from the quality factor, we obtained the energy loss of the propagating fourth sound, whose temperature and frequency dependences are not explained so far.

P-58. Development of MRI Microscope and its Application to Liquid ^{3}He-^{4}He Mixtures

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We are constructing a new magnetic resonance imaging system, "MRI Microscope" with much higher resolution, say 1 μm resolution. With the MRI Microscope, it will be possible for us to investigate shapes and surface properties of quantum fluids and solids in detail. In order to resolve an MRI image into an 1 μm×1 μm×1 μm volume, however, we have to obtain enough SNR from the small volume. By exploiting ultra low temperature and high magnetic field environment, we are trying to achieve the above goal. As the first stage of the development, we performed ULT-MRI to visualize the shape of interface between phase-separated ^{3}He-^{4}He mixtures at a higher magnetic field (0.92 T) using a stronger magnetic field gradient (0.5 T/m) than we did in 2000. We will discuss effects of magnetic fields by comparing present data to the previous ones.

P-59. Melting Shape of ^{4}He Crystal after Large Deformation

Y. Saitoh, T. Ueda, H. Abe, R. Nomura and Y. Okuda

(Department of Physics, Tokyo Institute of Technology)

By applying an acoustic wave to a vicinal surface of a ^{4}He crystal from the crystal side, it induced large deformation of the interface with crystallization. Clear facet appeared on the top of the deformation. When the acoustic wave was turned off, the facet shrank within a few milliseconds and a needle-like shape appeared above 500 mK. Thereafter, the needle-like shape relaxed to the initial flat surface slowly within a few hundreds of milliseconds. At lower temperatures the needle-like shape became unstable and the interface became very irregular during the first step of the relaxation. These anomalous shapes presumably originated from the superflow in the liquid phase induced by the fast interface motions.

P-60. Visualization of SN Interface of Liquid ^{4}He

J. Taniguchi, A. Ogino, R. Nomura and Y. Okuda

(Department of Physics, Tokyo Institute of Technology)

Super-normal (SN) interface was created by cooling liquid ^{4}He locally. For the local cooling the liquid ^{4}He was pumped through the impedance at the bottom of a Dewar and the SN interface appeared from the bottom. The SN interface moved upwards with further cooling and its motion was observed by a video camera. We applied heat pulses or acoustic pulses to manipulate the interface and the response of the interface to these perturbations was observed visually.

P-61. Anomalous Dynamics of Capillary Condensation in Aerogels

W. Miyashita, H. Kato, R. Nomura and Y. Okuda

(Department of Physics , Tokyo Institute of Technology)

A low porosity aerogel sucked the outer normal liquid ^{4}He with a clear interface. The interface proceeded as square root of time as predicted by the Washburn model of capillary condensation and the effective pore radius was obtained from the motion. For a high porosity aerogel two interfaces appeared during the condensation. The precursor interface proceeded slowly and the second interface appearing later caught up with the precursor one. Two effective pore radii were obtained for the each interface. Crossover between the two types of condensation was observed for an intermediate porosity aerogel. Variety of the dynamic must be a manifestation of the fractal nature of aerogels which had a wide distribution of the pore radii.

P-62. Gapless Spin Liquid in Two-dimensional ^{3}He under High Magnetic Fields

H. Nema, A. Yamaguchi, Y. Tanaka, H. Ishimoto

(Institute for Solid State Physics, University of Tokyo)

A Faraday-type magnetometer has been developed to measure the nuclear magnetization of monolayer ^{3}He films adsorbed on Grafoil at temperatures down to 0.1 mK under high magnetic fields up to 10T. The magnetic force is measured capacitively by monitoring the displacement of a wire-suspended copper plate, on which diffusion-bonded many copper foils are sandwiched by the Grafoil. To eliminate a large background signal from the Grafoil and copper, a double gradient coil system is employed. We report a preliminary result of the magnetization measurement for the 4/7 ^{3}He second layer film in a gapless spin liquid phase at 1.1 mK up to 10 T.

P-63. Nucleation and Growth of Stable Phase during the Magnetic Field Induced Phase Transition between U2D2 ^{3}He and CNAF ^{3}He

Takayoshi Tanaka, Yutaka Sasaki and Takao Mizusaki

(Department of Physics, Kyoto University)

We study the 1st order phase transition between U2D2 ^{3}He and CNAF ^{3}He, after a rapid change of the external magnetic field by ΔB through the critical field. A volume fraction of the metastable phase decreases in time and shows two-stage time evolution. The 1st stage shows an exponential decay, whose rate depends on ΔB. After a fraction of whole volume goes into a stable phase, slower 2nd stage takes over. Through the analysis on the 1st stage rate and the switching point between two stages, we propose the following scenario of the phase transition. After a nucleation of a seed of the stable phase, it grows with changing local temperature due to the latent heat. This seed stops growing when the local temperature reaches to a value corresponds to a shift of ΔB on the coexisting line between two phases. In this situation, unstable phase near this seed can not transform into a stable phase. Thus the 1st stage terminates at some point and a slower 2nd stage, where heat transport through liquid-solid interface controls the time evolution, takes over.

P-64. Spinwave and Sound in Nuclear Ordered Phases of Solid ^{3}He

Yoshiko Okamoto and Tetsuo Ohmi (Department of Physics, Kyoto University)

Spinwave velocity correction and magnon relaxation time are calculated by use of Holstein-Primakoff 1/S expansion. Sound velocity in the high field phase (HFP) of solid ^{3}He is also given as a function of magnetic field and temperature according to the methods similar to those developed by Khalatnikov et al. Anisotropy of the crystal is also taken into consideration as was done in the U2D2 phase and the kinetic equation and the Boltzmann equation are expanded with strain tensors. Sound attenuation which results from four-magnon processes is evaluated by means of collision-time approximation.

P-65. Ring-exchange-induced Quantum Phenomena in Strongly Correlated Electron Systems

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(JAEA, Spring-8[A], Tokyo Institute of Technology[B] , Kyushu University[C])

We theoretically investigate several exotic quantum phenomena caused by ring-exchange interactions in strongly correlated electron systems. The numerical exact diagonalization studies of finite-size clusters and perturbation approach of some spin and electron model systems indicate the following results:

(i) The Heisenberg spin ladder with sufficiently large ring-exchange exhibits a magnetization plateau at half the saturation magnetization [1]. And/or the system possibly has a field-induced incommensurate order parallel to the external magnetic field [2].

(ii) The ring-exchange can be one of the origins of the charge stripe in the square-lattice t-J model, which is supposed to be a model of high-T_c cuprates [3].

[1] A. Nakasu, K. Totsuka, Y. Hasegawa, K. Okamoto and T. Sakai, J. Phys. Condens. Matter **13** (2001) 7421.

[2] T. Sakai and K. Okamoto, J. Phys. Chem. Solids **66** (2005) 1450; N. Maeshima, K. Okunishi, K. Okamoto and T. Sakai, Phys. Rev. Lett. **93** (2004) 127203.

[3] T. Sakai, J. Phys. A: Math. Gen. **36** (2003) 9303.

P-66. Co-existence of Long-Range Order and Spin Fluctuation in a New Geometric Frustration System $M_2Cl(OH)_3$ [M = Cu^{2+}, Co^{2+}, Ni^{2+}, Fe^{2+}]

X.G. Zheng (Department of Physics, Saga University)

Transition metal hydroxide system of $M_2Cl(OH)_3$, where M represents 3*d* – electron magnetic ions of Cu^{2+}, Ni^{2+}, F^{e2+} and Co^{2+} etc., is found to be a new geometric frustration system for d-electron spins. The magnetic ions form a three-dimensional network of corner-sharing tetrahedrons resembling the *f* – electron pyrochlores. $Cu_2Cl(OH)_3$ has been found to undergo antiferromagnetic transition at T_N = 18.1 K, followed by a low-temperature ordered phase below 6.4 K with fluctuation coexisting with the long-range order. Further studies of this clean material system, we believe, would enrich the knowledge on geometric frustration and helps to understand the exotic quantum states exhibited by the geometrically frustrated systems.

P-67. Spin and Nematic correlation of *S* = 1 Triangular Antiferromagnet

Mitsuhiro Arikawa (Yukawa Institute for Theoretical Physics, Kyoto Universirty)

We have investigated the S = 1 antiferromagnet on triangular lattice. Especially we studied the spin and nematic correlation for the bilinear-biquadratic model at zero temperature based on bosonization, to understand the antiferromagneitc spin nematic order phase with three sublattice structure and its quantum fluctuation effects. We try to explain the spin liquid behavior in recently discovered $NiGa_2S_4$ compound.

P-68. Impurity Effects of the Spin Disordered State in $NiGa_2S_4$

Yusuke Nambu, Satoru Nakatsuji and Yoshiteru Maeno

(Department of Physics, Kyoto University)

Ni-site impurity effects of the spin disordered state in the triangular antiferromagnet $NiGa_2S_4$ [1] was studied through magnetic and thermal measurements for $Ni_{1-x}Zn_xGa_2S_4$ ($0.0 < x < 0.3$) and $Ni_{1-x}Co_xGa_2S_4$ ($0.0 < x < 0.5$). In Zn substituted systems, the T^2 dependent specific heat and its scaling behavior with the Weiss temperature indicate the existence of a coherent Nambu-Goldstone mode. Absence of either conventional magnetic order or bulk spin freezing suggests a hidden symmetry breaking of the ground state. We will also show our recent results of Co substituted systems.

[1] Satoru Nakatsuji, Yusuke Nambu, Hiroshi Tonomura, Osamu Sakai, Seth Jonas, Collin Broholm, Hirokazu Tsunetsugu, Yiming Qiu and Yoshiteru Maeno, Science **309**, 1697 (2005).

P-69. Magnetic Properties of $NiGa_2S_4$ Single Crystals

K. Onuma, Y. Nambu, S. Nakatsuji, H. Tonomura, O. Sakai, and Y. Maeno

(Department of Physics, Kyoto University)

$NiGa_2S_4$ is a quasi two-dimensional spin-1 antiferromagnet with exact triangular lattice. Thermodynamic and neutron measurements on polycrystalline samples of $NiGa_2S_4$ demonstrated that spins form a novel type of a disordered state below 10 K [1]. Here, we report the magnetic properties of high-quality single crystals of $NiGa_2S_4$. DC susceptibility measurements reveal the nearly T – independent behavior below 10 K, consistent with the polycrystalline results. We will also report the results of the specific heat measurements on single crystals.

[1] S. Nakatsuji, Yusuke Nambu, Hiroshi Tonomura, Osamu Sakai, Seth Jonas, Collin Broholm, Hirokazu Tsunetsugu, Yiming Qiu, and Yoshiteru Maeno, Science **309**, 1697 (2005).

P-70. Spin-Wave Analysis to the Multiple-Spin Exchange Model on the Triangular Lattice in the Magnetic Field

Chitoshi Yasuda, Daisuke Kinouchi and Kenn Kubo

(Department of Physics and Mathematics, Aoyama Gakuin University)

We study quantum effects of a three-sublattice structure in an $S = 1/2$ multiple-spin exchange model with two-, three- and four-spin exchange interactions on a triangular lattice in a magnetic field by means of the linear spin-wave method. This model is related to the nuclear magnetism of solid ^{3}He layers. We found that the coplanar umbrella state which is the ground state of the classical system survives quantum fluctuations and that the phase transition to the phase with the 6-sublattice structure occurs with a softening of the spin wave.

P-71. Order Parameters in the Multiple-Spin Exchange Model in the Magnetic Field

Yuma Uchihira, Chitoshi Yasuda, Kenn Kubo

(Department of Physics and Mathematics, Aoyama Gakuin University)

We investigated a ground-state phase diagram of the multiple spin exchange model with two-, four-, five- and six-spin interactions on a triangular lattice in a magnetic field, using conjugate gradient method within mean field approximation. We estimate order parameters in the phases with 6- and 12-sub lattice structure by structure factor concerning chirality correlation function. It is found that 6- and 12-sub lattice structure have staggered chirality.

P-72. Interplay between the Trimerization and the Frustration in Quantum Spin Chains

Kiyomi Okamoto [A], Akiyuki Tokunou [A] and Toru Sakai [B] (Department of Physics, Tokyo Institute of Technology[A], Spring-8, Japan Atomic Energy Agency [B])

We investigate the trimerized quantum spin chains with frustrations. In some cases the trimerization and the frustration compete with each other, while they cooperate in other cases.

For example as the former case, we find the reentrant quantum phase transition with respect to the XXZ anisotropy parameter in the phase diagram, and also the confluence of four Berezinskii-Kosterlitz-Thouless lines into one point .We will also discuss the effects of four-spin cyclic exchange interactions.

P-73. Crystal Distortion of Pyrochlore Compounds $Dy_2Ti_2O_7$, $Ho_2Ti_2O_7$ below about Spin-Ice Transition Temperature

H. Kaneko, F. Hata, Y. Xue, H. Ito, A. Savinkov and H. Suzuki

(Graduate School of Natural Science and Technology, Kanazawa University)

Geometrical frustration has been attracting much interest recently. Rare earth pyrochlore compounds, $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ show a spin-ice transition at 1 K. Due to a strong single-ion anisotropy, the ground state of Dy^{3+}(Ho^{3+}) is well expressed by an Ising doublet with local <111> quantization axes. In this situation, a ferromagnetic interaction leads to a strong geometrical frustration. The anisotropic thermal expansion measured by x-ray diffraction was observed in $Dy_2Ti_2O_7$ below 1.5 K. FWHM also increased below 1.5 K.

Theses experimental results suggest the crystal distortion of $Dy_2Ti_2O_7$ below 1.5 K. We will also report the x-ray diffraction of $Ho_2Ti_2O_7$.

P-74. Unconventional criticality of Mott transition in a quasi-two-dimensional organic conductor

Fumitaka Kagawa, Kazuya Miyagawa, Kazushi Kanoda

(Department of Applied Physics, University of Tokyo)

We report the unconventional criticality of Mott transition found in the quasi-two-dimensional organic conductor, κ-$(BEDT\text{-}TTF)_2Cu[N(CN)_2]Cl$, using conductance measurements under continuously controllable pressure. The obtained critical exponents are different significantly from the conventional cases. The successful scaling law of the data points to a novel criticality that has never seen in any other phase transition. The present results possibly give the starting point for the comprehensive understanding of diverse electronic states found near the Mott transition in quasi-two-dimensional systems. We also report the recent NMR results of Mott criticality.

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