

## 低温物質科学研究センター - セミナ - 報告

日時：2003年10月28日（火） 午後4時～5時30分

場所：理学研究科5号館 物理学教室439号室

講師：田山 孝 氏

所属：東京大学物性研究所・新物質科学研究部門

題目：Low Temperature Magnetization of the Heavy Fermion Superconductor CeCoIn<sub>5</sub>

要旨：

We present low temperature dc magnetization measurements on the layered structure heavy fermion superconductor CeCoIn<sub>5</sub> with  $T_c=2.3$  K, revealing a first-order phase transition (FOPT) at the upper critical field  $H_{c2}$  for both  $H//a$  and  $c$  axes below  $0.3T_c$  [1]. The  $M(H)$  data at 1.6 GPa for  $H//c$  still shows a clear FOPT at  $H_{c2}$ , although the superconducting condensation energy significantly decreases. We also found an unusual peak effect for  $H//c$  and the FFLO phase transition for  $H//a$ , which was recently observed in the specific heat measurements [2]. Possible physical mechanisms of the observed phenomenon will be discussed.

[1] T. Tayama *et al.*, Phys. Rev. B **65**, 180504 (2002).

[2] H.A. Radovan *et al.*, Nature **425**, 51 (2003).

日時：2003年10月31日（金） 午前10時30分～12時

場所：理学研究科5号館 物理学教室439号室

講師：Prof. Collin Broholm

所属：Department of Physics and Astronomy, Johns Hopkins University

題目：Imaging the Quantum Interference of Cuprate Quasiparticles

要旨：

Magnetic materials generally develop long range order at temperatures similar to the characteristic spin-interaction energy scale. However, weak connectivity and competing interactions can suppress static spin order and give rise to qualitatively different strongly correlated states of matter. I shall discuss neutron scattering experiments that characterize such novel phases in illustrative model systems of varying complexity. The focus shall be on lattices of corner-sharing simplexes wherein the dominant interactions can be satisfied without long range order. La<sub>4</sub>Cu<sub>3</sub>MoO<sub>12</sub> for example contains a lattice of weakly interacting copper spin triangles [1]. Pulsed neutron scattering experiments show that inter-triangle interactions are satisfied through adoption of a Kramer's doublet ground state. A phase transition to long range order amongst the residual composite spin was detected at temperatures more than two orders of magnitude below the characteristic exchange energy. Quasi-two-dimensional SrCr<sub>9p</sub>Ga<sub>12-9p</sub>O<sub>19</sub> [2,3] and QS-Ferrite [4] both contain triangular latticelayers sandwiched between two kagome' lattices. Samples studied sofar do not achieve long range spin order at any

temperature. Instead there is local order within simplexes and the spin relaxation rate decreases with T until a spin freezing transition at a few percent of the Curie-Weiss temperature.  $\text{ZnCr}_2\text{O}_4$  is a cubic lattice of corner-sharing tetrahedra with substantially more complex behavior. We show that tetrahedra that are connected to form hexagons develop fluctuating spin director degrees of freedom. This spin director paramagnet is however unstable towards a lattice deformation that relieves frustration and enables long range spin order.

1. Y. Qiu, C. Broholm, S. Ishiwata, M. Azuma, M. Takano, R. Bewley, and W. J. L. Buyers, cond-mat/0205018.
2. S. H. Lee, C. Broholm, G. Aeppli, A. P. Ramirez, T. G. Perring, C. Carlile, M. Adams, and B. Hessen, Europhys. Lett. **35**, 127 (1996).
3. S.-H. Lee, C. Broholm, G. Aeppli, T. G. Perring, and B. Hessen, Phys. Rev. Lett. **76**, 4424 (1996).
4. G. Gasparovic, S.-H. Lee, C. Broholm, and R. J. Cava, unpublished (2003).
5. S.-H. Lee, C. Broholm, W. Ratcliff II, G. Gasparovic, Q. Huang, T. H. Kim, and S.-W. Cheong, Nature **418**, 856 (2002).
6. S.-H. Lee, C. Broholm, S.-W. Cheong, T.H. Kim, and W. Ratcliff II, Phys. Rev. Lett. **84**, 3718 (2000).

日時：2003年11月10日(月) 午後4時~5時30分

場所：理学研究科5号館 439号室

講師：Dr. R.A. Borzi and Dr. S.A. Grigera

所属：University of St. Andrews, Scotland, UK

題目：Quantum criticality and metamagnetism in the Ruthenate  $\text{Sr}_3\text{Ru}_2\text{O}_7$

要旨：

Quantum criticality may provide a unified framework for understanding many facets of strongly correlated electron behaviour of solids. Furthermore, entirely novel behaviour is often seen in the close vicinity of quantum critical points. In this talk we will discuss the bilayer ruthenate metal  $\text{Sr}_3\text{Ru}_2\text{O}_7$ .

We will show evidence for the presence of a magnetic-field-tuned quantum critical point and discuss the nature of such a point. In addition, we will show the presence of unusual properties that become much more pronounced as the disorder level is reduced.

日時：2003年11月14日(金) 午後3時~

場所：理学部1号館 化学教室第一会議室

講師：Professor Sankar Chakravorti

所属：Indian Association of the Cultivation of Science, INDIA

題目：Effect of hydrogen bonding on excited state charge transfer dynamics

要旨：

Since the observation of dual emission of 4-N,N,-dimethylaminobenzonitrile (DMABN) by Lippert et al and the subsequent explanation of dual emission in terms of Twisted Intramolecular Charge Transfer (TICT) and Locally excited state (LE) by Grabowski et al, lot of interested was generated in different laboratories investigating this molecule and also other molecules having a donor and acceptor moiety connected by essential

single bond. Myriad of experimental and theoretical results on the ICT nature of DMABN have already been published. Though three different mechanisms viz, TICT, PICT and RICT have so far been proposed but the former one is popular. Whilst much work continue to concentrate on determining the structures of the LE and TICT states, the precise nature of the difference between the properties of the excited state in protic and aprotic solvents is little understood. For example, the fluorescence quantum yield of DMABN in protic solvents is lower and the fluorescence spectrum is further red shifted and broadened, relative to aprotic solvents of same polarity and the fluorescence decay kinetics are difficult to interpret. The present talk is addressed to this problem relating to our results on 4 N,N-dimethylaminocinnamaldehyde (DMACA) and also some other important results in this context.

日時：2003年11月27日（木） 午後4時～

場所：理学研究科5号館 439号室

講師：Prof. E.V. Sampathkumaran

所属：Visiting Professor, ISSP, University of Tokyo, Tata Institute of Fundamental Research

題目：Magnetic anomalies and geometrical frustration effects in spin-chain oxides of the type,  $A_3MXO_6$

要旨：

We have been investigating a class of spin-chain compounds of the type  $A_3MXO_6$ , derived from  $K_4CdCl_6$  type rhombohedral structure, and found many interesting magnetic anomalies. All these results will be reviewed. Particular emphasis will be placed on  $Ca_3CoXO_6$  ( $X = Rh, Ir$  and  $Co$ ) serving as new examples for *spin-glass* behavior, that too of *an unusual type, among stoichiometric compounds due to geometrical frustration effects*. Creation of disorder by chemical substitution (say, by doping Mn for Co) restores long range magnetic ordering (exactly opposite to what has been known in magnetism till to date), as though the geometrical magnetic frustration is released by disorder.

日時：2003年12月5日（金） 午前10時30分～

場所：理学研究科5号館 519号室

講師：Dr. M. E. Zhitomirsky

所属：Theory Group, SPSMS/DRFMC, CEA-Grenoble, France

題目：Geometrically frustrated magnets in external field

要旨：

Applied field has dramatic effect on magnets with geometric frustration. We compare finite-field behavior of several frustrated magnets including classical Heisenberg antiferromagnets on kagome, garnet and pyrochlore lattices, and XY checker-board antiferromagnet. The thermal order by disorder effect stabilizes in these strongly frustrated magnets a number of unusual phases: states with triatic (third-rank tensor) order parameters at low and high magnetic fields and collinear spin-liquid states at one-third or one-half of the saturation.

The quantum order by disorder effect is examined for the high-field phase transition from the saturated state for the frustrated square lattice and the face centered cubic lattice antiferromagnets. In the fully saturated phase the magnon spectra for the two models have lines of minima. Transition into partially magnetized state is treated

via a mapping to Bose condensation of single-flip magnons with anomalous dispersion. The asymptotic behavior of the magnetization curve differs significantly from that of conventional antiferromagnet in  $d$ -spatial dimensions.

We also examine the magnetothermodynamics of a number of frustrated magnets. The field induced adiabatic temperature change is significantly larger for such systems compared to ordinary non-frustrated magnets and also exceeds the cooling rate of an ideal paramagnet in a wide range of fields. An enhancement of the magnetocaloric effect is related to presence of a macroscopic number of soft modes in frustrated magnets below the saturation field. The obtained results suggest that frustrated magnets can be used as novel refrigerant materials in adiabatic demagnetization refrigerators. Analytical predictions are confirmed with extensive Monte Carlo simulations.

日時：2003年12月10日（月） 午後16時分～

場所：理学研究科5号館 439号室

講師：Dr. Alexander Gabovich

所属：Institute of Physics of the National Academy of Sciences of Ukraine, Kiev, Ukraine

題目：Spin-dependent tunnel currents in junctions between ferromagnets and normal metals (superconductors) with charge-density waves

要旨：

A new experimental scheme to study a spin polarization  $P$  of ferromagnets is proposed. Specifically, normal or superconducting metals partially gapped by charge density waves (CDWs) are suggested as a probe of  $P$  while measuring dynamic conductivity  $G(V)$  of tunnel junctions between CDW metals and ferromagnets in external magnetic fields. Calculated  $G(V)$  are substantially different from those in the case of the superconductor-insulator-ferromagnet structures, being well-known probes of  $P$ . The existing variety of CDW substances with critical temperatures and energy gaps substantially exceeding their superconducting counterparts constitute an advantage of the proposed set-up.

日時：2003年12月16日（火） 午後3時～

場所：理学研究科5号館 第4講義室

講師：Dr. Robin Perry

所属：International Innovation Center, Kyoto University

題目：Consequences of proximity to a metamagnetic quantum critical point  
- Anomalous behaviour in  $\text{Sr}_3\text{Ru}_2\text{O}_7$  -

要旨：

Quantum criticality is currently generating large interest in the solid state physics community because of its potential to describe strongly correlated electron systems in a wide perspective. Novel electronic states of matter, for example unconventional superconductivity, have been observed close to quantum critical points. In this seminar, I present the latest data on the ultra-pure single-crystals of  $\text{Sr}_3\text{Ru}_2\text{O}_7$ , which is close to a metamagnetic quantum critical point. We observe dramatic and unexplained behaviour in the bulk properties close to the critical field; a broad peak in the resistivity that is bounded by first order phase transitions. This

anomalous behaviour is enhanced as the disorder level is decreased suggesting that it is intrinsically electronic in nature and not a consequence of impurities.

日時：2003年12月17日(水) 午後4時～

場所：理学研究科5号館 439号室

講師：Christopher Bäuerle

所属：Low Temperature Research Laboratory, CRTBT-CNRS, BP 166, 38042 Grenoble Cedex 9, France

題目：Electron Coherence in Mesoscopic Kondo Wires

要旨：

The understanding of the ground state of an electron gas at zero temperature is one of the major challenges in Solid State Physics. For a long time it has been known that such a ground state is well described by Landau's theory of Fermi liquids [1]. In this description, the lifetime of quasiparticles is infinite at zero temperature, as the coupling to the environment tends to zero. Alternatively, in mesoscopic physics, one key physical concept is the phase coherence time, *i.e.* the time an electron can travel in a solid before it loses its phase coherence and thus its quantum, wave like behaviour. Such a decoherence is due to inelastic processes, like electron-phonon, electron-electron or electron-photon collisions. It has been shown by Altshuler and coworkers [2] that the phase coherence time diverges at zero temperature as electron-phonon, electron-electron and electron-photon interactions all go to zero at zero temperature. However, recent experiments on metallic as well as semiconductor wires suggest that the phase coherence time saturates at very low temperature [3]. Following this work, it has been argued that the observed saturation is indeed universal and intrinsic, and due to electron-electron interactions in the ground state of the Fermi liquid [4] which has sparked a relatively heavy debate in the mesoscopic community. More recent experiments invoke the coupling to magnetic impurities as a possible source of the frequently observed low temperature saturation of the phase coherence time [5-7]. In this talk we will review shortly recent experimental progress on the dephasing issue. In particular we will concentrate on the influence of magnetic impurities on the phase coherence time in mesoscopic quantum wires. We will show that the interactions between the magnetic impurities even in very dilute systems lead to a saturation of the phase coherence time at low temperatures [6] and are hence important for the issue of electron coherence in metallic conductors.

[1] D. Pines and P. Nozières, *The Theory of Quantum Liquids*, W.A. Benjamin (1966).

[2] B.L. Altshuler, A.G. Aronov and D.E. Khmel'nitskii, *J. Phys. C* **15**, 7367 (1982).

[3] P. Mohanty, E.M.Q. Jariwala and R.A. Webb, *Phys. Rev. Lett.* **78**, 3366 (1997).

[4] D.S. Golubev and A.D. Zaikin, *Phys. Rev. Lett.* **81**, 1074 (1998).

[5] F. Pierre and N.O. Birge, *Phys. Rev. Lett.* **89**, 206804 (2002).

[6] F. Schopfer, C. Bäuerle, W. Rabaud and L. Saminadayar, *Phys. Rev. Lett.* **90**, 056801 (2003).

[7] A. Anthore, F. Pierre, H. Pothier and D. Esteve, *Phys. Rev. Lett.* **90**, 076806 (2003).

日時：2003年12月18日（木） 午後4時～

場所：低温物質科学研究センター - 2F 会議室

講師：上野 智弘 氏

所属：低温物質科学研究センター -

題目：3重臨界点近傍でのHe3-4混合液体相分離界面の接触角の振る舞い

要旨：

京都大学において開発された超低温MRIにより、He3-4混合液体の相分離界面が像化された。そのMRI画像により得られた相分離界面と壁とのなす角、"接触角"は、低温での小さな値から、3重臨界点近傍に近づくとつれ、大きくなるという温度依存性を示した。しかし、解像度の不足により、臨界点近傍での測定値は、測定値程度の誤差をもつものであったため、その振る舞いを決定できるに至らなかった。その後、パリ高等師範学校における光の干渉を用いた測定により、0.81 Kから0.86 Kまで、接触角が有限であり、温度とともに増加することが明らかになった。この温度依存性は、一般に成立すると信じられている"臨界濡れ現象"の例外にあたる。これは、界面に働く長距離相互作用が存在すれば、発生可能なものであり、He3-4混合液体においてはその相互作用が、臨界カシミア効果によるものと説明された。しかし、その説明において無視された短距離相互作用等が重要になるであろう0.86 Kから臨界点(0.87 K)での接触角の振る舞いは明らかにされていない。この振る舞いを大きな磁場勾配と高周波数を用いたMRI顕微鏡により、明らかにできる可能性がある。3重臨界点近傍における接触角の振る舞いのもたらす物理と、その測定を可能とするMRI顕微鏡の技術について議論する。

日時：2001年1月6日（火） 午後4時～5時

場所：理学研究科5号館 439号室

講師：澤田 安樹 氏

所属：東北大学 大学院理学研究科

題目：複合フェルミオン間の相互作用

要旨：

量子ホール効果は、低温・強磁場下で2次元電子系のホール抵抗がマクロに量子化される特異な物理現象である。量子ホール効果には、整数量子ホール効果と分数量子ホール効果が存在する。分数量子ホール効果は、偶数本の磁束量子を電子に付着させた複合フェルミオンの整数量子ホール効果として理解できる。しかしこれまで複合フェルミオン間の相互作用は、相互作用を有効質量の中に繰り込んだ一体近似で扱われ、あらわに相互作用を議論することはなかった。

そこで我々は、2層系  $\nu = 2/3$  分数量子ホール状態には、3種類の異なる量子ホール状態が存在することを実験で示し、総電子密度と電子密度差に関する相図を作成した。その結果、2種類の相境界の存在から、有効質量に相互作用を繰り込むだけでは一体近似の描像が破綻し、電子と同程度のクーロン相互作用が複合フェルミオン間にも働いていなければ、相図を理解できないことを明らかにした。

参考文献：N. Kumada et al. Phys. Rev. Lett. **89**, 116802 (2002).

日時：2004年1月23日（金） 午前10時30分～

場所：理学研究科5号館 第4講義室

講師：Pr. Tae Won Noh

所属：School of Physics, Seoul National University, Korea

題目：Optical Investigation on Metal-Insulator Transitions (MIT) of Pyrochlore transition metal oxides.

要旨：

Using optical spectroscopy techniques, we investigated optical properties of some 4d transition metal oxides, including  $R_2\text{Mo}_2\text{O}_7$  ( $R$ =rare earth metals) and  $(\text{Bi},\text{Y})_2\text{Ru}_2\text{O}_7$ , which have interesting MITs. In spite of the extended nature of the 4d orbitals, we found that the electron-electron correlation could play important roles in the MITs. By comparing the optical responses with numerous Hubbard models, we will also discuss on the importance of orbital degeneracy and geometric frustration in the MITs observed in these pyrochlore compounds.

日時：2004年2月6日（金） 午後3時～

場所：理学研究科5号館 439号室

講師：Pr. Oscar BERNAL

所属：Visiting Associate Professor, International Innovation Center, Kyoto University, Associate Professor, Department of Physics and Astronomy, California State University, Los Angeles

題目：Hidden Order/Disorder at Ambient Pressure Sampled by NMR in Powdered  $\text{URu}_2\text{Si}_2$

要旨：

Below the hidden order transition temperature  $T_0 \sim 17\text{K}$ , ambient-pressure  $^{29}\text{Si}$  and  $^{99}\text{Ru}$  NMR spectra in an aligned powder of  $\text{URu}_2\text{Si}_2$  reveal local internal field distributions at both  $^{29}\text{Si}$  and  $^{99}\text{Ru}$  sites. From temperature and applied-field orientation studies, we find that the internal fields are isotropic at the  $^{29}\text{Si}$  sites, but anisotropic at  $^{99}\text{Ru}$  positions, being larger in the  $ab$ -plane. The temperature dependence of the internal field distributions is found to be different for different field orientations also. While the  $^{99}\text{Ru}$  spectra for a longitudinal field orientation display a minority ferromagnetic phase, this phase is not seen in the corresponding spectra for perpendicular geometry. The majority phase in the  $^{99}\text{Ru}$  spectra also appears to change differently for different field orientations. We propose disorder in the non-magnetic sector as a way to understand our measurements and at the same time reconcile them with the occurrence of a transition to hidden order.

日時：2001年2月18日（水） 午後4時～

場所：理学研究科5号館 439号室

講師：松木 征史 氏

所属：京都大学化学研究所・原子核科学研究施設

題目：ダークマターアクシオン探索装置CARRACK：

リドベルグ原子を用いた低温でのマイクロ波単一光子検出

要旨：

宇宙におけるダークマターの正体の解明は素粒子物理・宇宙物理に関係する最重要な課題の一つで

あるが、素粒子アクシオンはその有力な候補である、アクシオンは強磁場中でマイクロ波光子に転換されるが、転換される確率は極めて小さい、この為、転換されたマイクロ波光子を、低温下で個々に検出する単一光子検出法が、アクシオン検出には有効である、高励起リドベルグ原子を用いて、低温でマイクロ波単一光子検出を行う装置CARRACKを紹介する、この装置では、超電導磁石により発生した強磁場下において、10mK領域に冷却されたマイクロ波共振空洞内でアクシオンを光子に転換し、転換された光子をリドベルグ原子に吸収させて、フィールドイオン化の方法により検出する、装置の構成、感度とその限界について述べる、