2012B期 採択長期利用課題の紹介

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2012B期は4件の長期利用課題の応募があり、3件が採択されました。採択された課題の審査結果および実験責任者による研究概要を以下に示します。

ー採択課題1ー

課題名	Development of spin-resolved Compton scattering in high magnetic fields: probing the orbitals in complex oxides
実験責任者名	Jonathan Duffy (University of Warwick)
採択時の課題番号	2012B0045
ビームライン	BL08W
審査結果	採択する

〔審査コメント〕

This group proposes to develop studies of magnetic systems and their interactions under high magnetic fields of up to 9 T and temperatures down to 1.5 K, using high energy magnetic Compton scattering at BL08W. Their research program focuses on gaining understanding of complex magnetic oxides, in particular on the multiferroics, and heavy Fermion materials metamagnetism. The common physics behind them is “orbitals in complex materials”. For this purpose, they will bring their Oxford Instruments “Spectromag” cryomagnet to SPring-8.

The committee agrees that the magnetic Compton scattering spectrometer equipped with the new superconducting magnet system proposed by the group allows novel measurements of spin densities in multiferroics, iridates, ruthenates and heavy fermion materials, all of which are interesting and relevant materials both scientifically and technologically. Then, the installation of such an instrument at a Compton scattering beamline BL08W will certainly not only provide unique and new messages to the science in proposed materials, but also extend performance of the current magnetic Compton scattering spectrometer at BL08W. Also, the research group has much experience in Compton scattering both at SPring-8 and ESRF, and in theoretical modeling of electronic structures, and has close collaboration with sample providers. Therefore the committee judges that this proposal is highly feasible, and as a result will bring significant contributions to materials science.

Although several interesting materials are proposed, the road map of the research has not been shown in the proposal and at the presentation given by Prof. Duffy. The committee requests the group to draw up a time schedule to assure the steady progress of research in the next three years.

〔実験責任者による研究概要〕

The purpose of this project is to develop studies of magnetic systems and their interactions under high magnetic fields of upto 9 T and temperatures down to 1.5 K, using high energy magnetic Compton scattering. Until now, experiments on BL08W have been limited to a maximum field of 2.5 T and minimum temperature of ~6 K. The main proposer has an x-ray compatible Oxford Instruments “Spectromag” cryomagnet suitable for these experiments, which will be transferred to BL08W for the duration of the project. Our research programme is focussed on gaining understanding complex magnetic oxides, concentrating in particular on the multiferroics that are expected have an important role in the development of spintronic applications. During the course of this project, the magnet will also be available for other scientific users of BL08W.

Magnetic Compton scattering (MCS) samples the spin dependent electron momentum density through the use of circularly polarised synchrotron radiation. MCS is sensitive to only the spin moment of the sample. The technique requires a high energy monochromatic beam of circularly polarised photons at an energy of approximately 175 keV, and high scattering angles of approximately 170 degrees, in order to obtain good resolution. In order to extract the spin polarised signal two measurements are made with parallel and antiparallel applied field directions with respect to the scattering vector, the magnetic Compton profile is determined by the subtraction of the two spectra. There are several important reasons for developing the high field method. Measurements of a considerably wider range of materials, including those which have interesting high-field behaviour, such as metamagnetism will become possible. Furthermore, in many small-moment systems the high field will induce a larger moment, making measurements more sensitive.

The impact of our research has replies on our ability to perform detailed electronic structure calculations using a variety of techniques. Our research collaboration includes and involves directly experts in the calculaton methods. It is the direct interaction between experiment and theory that maximises the potential of magnetic Compton scattering. Our approach involves more than just comparison of experiment with theory: we use the experiments to inform the underlying physics involved with the calculations, and we use different theoretical approaches in combination.

Our research programme concentrates on complex oxide systems. These can be found in almost every possible solid physical state as superconductors, metals, insulators, ferromagnets, ferroelectrics, multiferroics and more. Many are transition metal oxides with strong electron correlations that lead to fierce competition between lattice, orbital, charge and spin interactions. Recent advances in their design and fabrication establish the means to tailor their response for applications.

―採択課題２―

課題名	X線分光法による臨界価数ゆらぎによる新しい量子臨界現象の実験的検証
実験責任者名	渡辺真仁（所属：九州工業大学）
採択時の課題番号	2012B0046
ビームライン	BL39XU
審査結果	採択する

〔審査コメント〕

本申請課題は、4f電子系における量子臨界現象に対して提案された価数ゆらぎによる理論的予測を高圧・強磁場下でX線分光実験をおこなって検証することを目指している。

最近、従来用いられてきたスピンゆらぎの理論では説明できない量子臨界現象がYb化合物で発見され、申請代表者らがYbの価数ゆらぎによる量子臨界現象による理論を提唱している。本申請課題では、研究の対象をYb化合物だけでなく、電子正孔対称物質であるCe化合物にもひろげて理論の一般性を証明することを目的としており、理論の検証によって得られると期待される成果は基礎科学的に重要である。また、これまで強相関電子系物質の研究実績が豊富な研究者が共同実験者となっており研究成果も期待できる。

一方、申請書の記述および審査委員会における説明でも、理論の検証のために長期利用課題を申請する根拠とその道程が明快に示されたとはいいがたい。本研究で開発すべき極低温・強磁場下高精度圧力測定システムおよびCe化合物用ダイヤモンドアンビルセル（DAC）についても十分な検討がなされているか不明確である。前者に関しては、ビームライン担当者の寄与がかなり求められると考えられるが、申請書はビームライン担当者を共同実験者としていない。また、Ce化合物の実験に十分使用できる薄いDACが長期利用期間中に確実に開発可能かどうかもはっきりとせず不安が残る。現在入手可能な試料について現状の技術を組み合わせて実験し、ある程度の成果を得て満足するのであれば長期利用課題として申請する意味も薄れることになりかねない。

以上のように、本申請課題は基礎科学的重要性から長期利用課題としてその採択を決定するが、研究の実施にあたっては、共同実験者にビームライン担当者を加えるとともに、長期利用課題として技術的に達成しようとする目標とそこに至る行程を明確に設定し、それぞれの試料についてどう系統立てて実験していくのか十分検討することを強く望む。

〔実験責任者による研究概要〕

本研究は、YbやCeを含む強相関電子系物質における、新しい量子臨界現象の起源をX線分光法により明らかにすることを目的とする。

磁場や圧力を変化させたときに、磁気相転移の温

度が絶対零度に抑制された場合に実現する磁気量子臨界点近傍では、低温で電気抵抗や比熱などの物理量が異常な振る舞いを示す量子臨界現象が生じることが知られており、これまでスピンゆらぎの理論によってよく説明されると考えられてきた。しかしながら、2000年に従来とは異なる新しいタイプの量子臨界現象が、重い電子系金属$YbRh_2Si_2$で発見され、強相関電子系において大きな問題となっている。さらに、2008年に別のYb系金属b-$YbAlB_4$でも$YbRh_2Si_2$とよく似た量子臨界現象が発見されたことから、これらの物質が新しい普遍性クラスを形成している可能性が出てきた。

最近、Ybの価数転移の温度が絶対零度に抑制された価数量子臨界点の近傍で、Ybの臨界価数ゆらぎにより、新しいタイプの量子臨界現象が引き起こされることが理論的に示され、$YbRh_2Si_2$やb-$YbAlB_4$が示す非従来型の量子臨界現象が自然に説明されることが明らかとなった（S. Watanabe *et al*., Phys. Rev. Lett. **105** (2010) 186403）。この理論によれば、Ybの4f電子の軌道と伝導電子の軌道の間の電荷移動のゆらぎが様々な物性異常を引き起こす起源であり、上記以外のYb系物質や、Yb系と電子-正孔対称の関係にあるCe系物質でも同様の現象が観測される可能性が指摘されている。

そこで、本長期利用課題では、X線分光法を用いて臨界価数ゆらぎの理論の実験的検証を行い、新しい量子臨界現象の起源の実験的解明に挑む。具体的には、高圧・強磁場・低温の極限環境下で、非従来型の量子臨界現象を示す複数の候補物質のYbおよびCeの価数を精密に測定し、YbおよびCeの価数転移の量子臨界点の探索を行う。X線分光法による価数測定と電気抵抗などのマクロ物性の測定を同一環境下で行うことにより、圧力、磁場、温度の3次元相図を正確に決定し、価数転移の量子臨界点近傍で電気抵抗などの物理量に異常な量子臨界現象が発現する可能性を検証する。そのために、SPring-8のBL39XUにおいて、(1) X線分光測定とX線回折、および電気抵抗などの物理量を、高圧・強磁場・極低温の同一環境下で測定可能なシステムの開発、(2) Ce系化合物のX線分光測定を可能にする薄いダイヤモンドアンビルセルの開発、(3) YbおよびCeの価数を高精度で測定するために、多重極限環境下でのX線吸収分光とX線放出分光を組み合わせた手法の確立、に取り組む。

ー採択課題 3 ー

課題名	Phase Contrast X-ray Imaging of the Lung
実験責任者名	Stuart Hooper（Monash University）
採択時の課題番号	2012B0047
ビームライン	BL20B2
審査結果	採択する

〔審査コメント〕

The proposer's group has been working on the lung function after birth with the refraction-enhanced imaging technique. BL20B2 at SPring-8 is the most suitable beamline world-wide for such phase-contrast imaging experiments because of its small X-ray source size and the long distance from the source to the experimental station. Thus, this group is making the best use of the beamline.

This is the third long-term proposal from this group. In the first proposal, they worked on new born rabbit pups and showed that the lung aeration at birth is mainly facilitated by breathing, a view that was drastically different from the previous hypothesis that was based on continuous water transfer by osmotic pressure. In the second proposal, they showed that lung aeration of very premature infants can be improved with the help of modified ventilation methods such as positive end-expiration pressure or sustained inflation. These findings have already led to changes in clinical guidelines. Along with these medical achievements, the group developed several new methods to analyze the phase-contrast images. They devised an algorithm to measure regional lung gas volumes from the X-ray images and introduced the techniques of particle image velocimetry to visualize the three-dimensional movements of ribs and lung during breaths. The committee highly evaluates these achievements which demonstrated that synchrotron radiation can be an important tool in medicine.

In this third long-term proposal, the group is aiming to continue studies on the neonates to find a better way of ventilation and expand it to other important diseases such as asthma, together with further technical developments. Although several medical and technical goals are set, the road map of the research has not been shown. The committee requests the group to draw up a time schedule to assure the steady progress of research in the next three years.

〔実験責任者による研究概要〕

Research Purpose and Summary

Lung disease and respiratory failure is a major cause of death and long-term disease in adults, children and particularly in newborn infants. Therefore, understanding the progression of lung disease and how respiratory failure occurs, especially in the newborn, will contribute to improved healthcare for many members of society. The huge potential that phase contrast (PC) X-ray imaging offers for the study of lung diseases resides within its ability to image the lung in great detail, particularly the small airways, which harbour much of the pathology. PC X-ray imaging greatly enhances image contrast by using the phase shift of X-rays as they propagate through objects with different refractive indices. The air-tissue interfaces within the lungs yield phase shifts that are large enough to make the normally invisible air-filled structures of the lung highly visible. No other imaging modality can provide video speed images that reveal the airways at micron scale in living, breathing animals.

Our proposed research program has two major objectives that will exploit the major advances we have previously made in PC X-ray imaging and experimental procedures. Our **first aim** focuses on important biomedical questions in lung biology such as:

a. How can we better ventilate and resuscitate very premature infants without injuring their very delicate, immature lungs?
b. How do asthma and other airway diseases (eg. bronchitis) that increase airway resistance affect regional lung function?

Our **second aim** is to continue developing imaging and analytical techniques that allow us to answer major biomedical questions in neonatal and adult lung biology.

Expected Outcomes

This long-term proposal will extend our investigations of the transition of the newborn at birth and results will impact on the clinical management of premature newborn infants. In particular, we expect that our work will:

i. Identify the best possible procedures that can be used to facilitate uniform lung aeration at birth without causing injury
ii. Determine how partial lung aeration triggers an increase in pulmonary blood flow in un-aerated regions of the lung at birth
iii. Identify the interaction between ventilation of the lung at birth and compromised cerebral vascular perfusion, including haemorrhage.

This long-term proposal also aims to understand and identify the effect of changes in lung structure on lung function in adult lung disease using PC X-ray imaging. In particular, we expect that our work will:

i. IDetermine the effects of asthma and inhaled bronchodilators used to treat asthma, on regional lung function
ii. Determine the ability of PC X-ray imaging to characterise morphological changes in lung structure associated with lung pathologies

Another important aspect of this proposal is continued development and refining of our imaging and analytical techniques so that we can better answer these complex biomedical questions. In particular, we will:

(i) Continue developing techniques to digitally subtract the ribcage from lung tissue to more accurately measure air volumes and track lung movement
(ii) Develop techniques to perform PC X-ray imaging and angiography in the brain to investigate relationships between lung aeration and cerebral vascular compromise
(iii) Develop imaging and analytical techniques to assess the size distribution of distal airway structures and how they change with disease