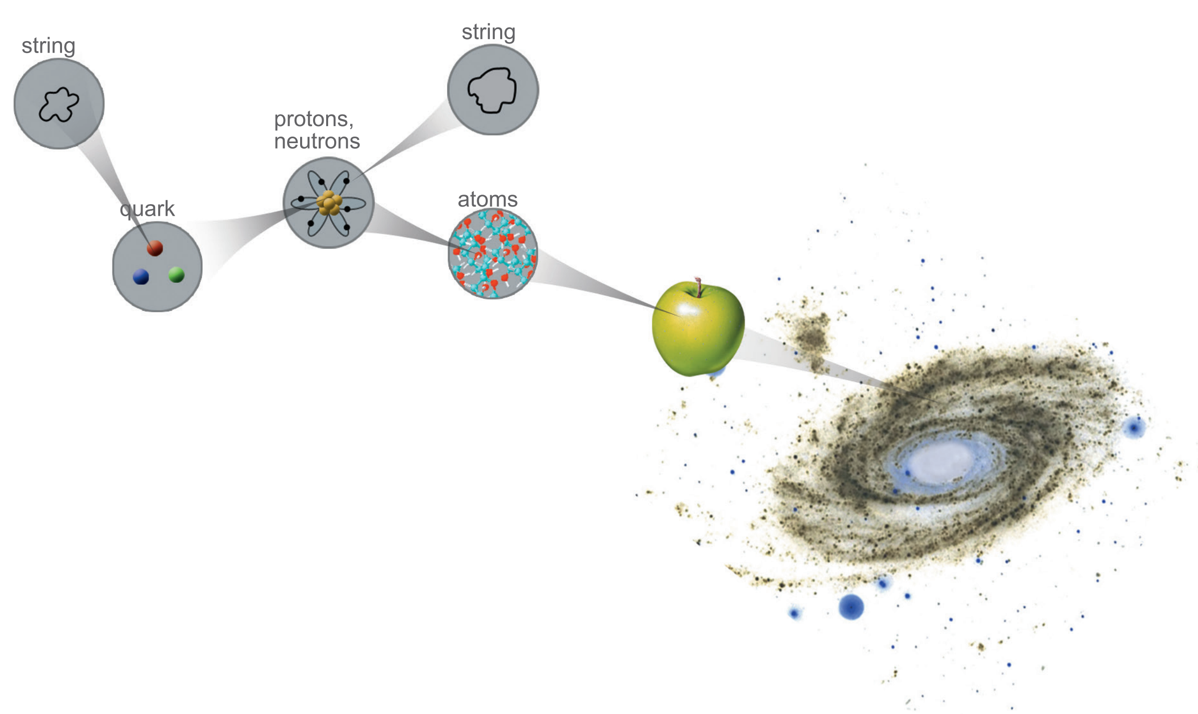

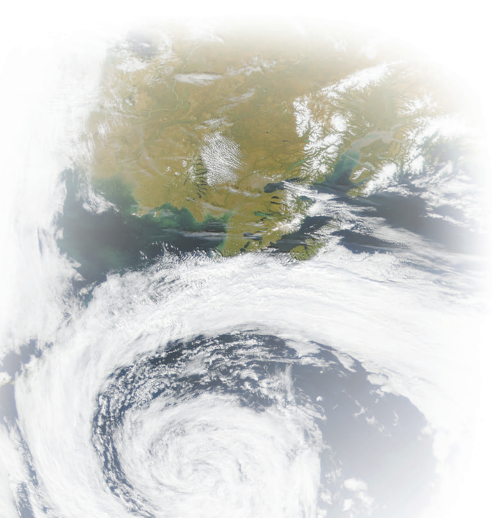

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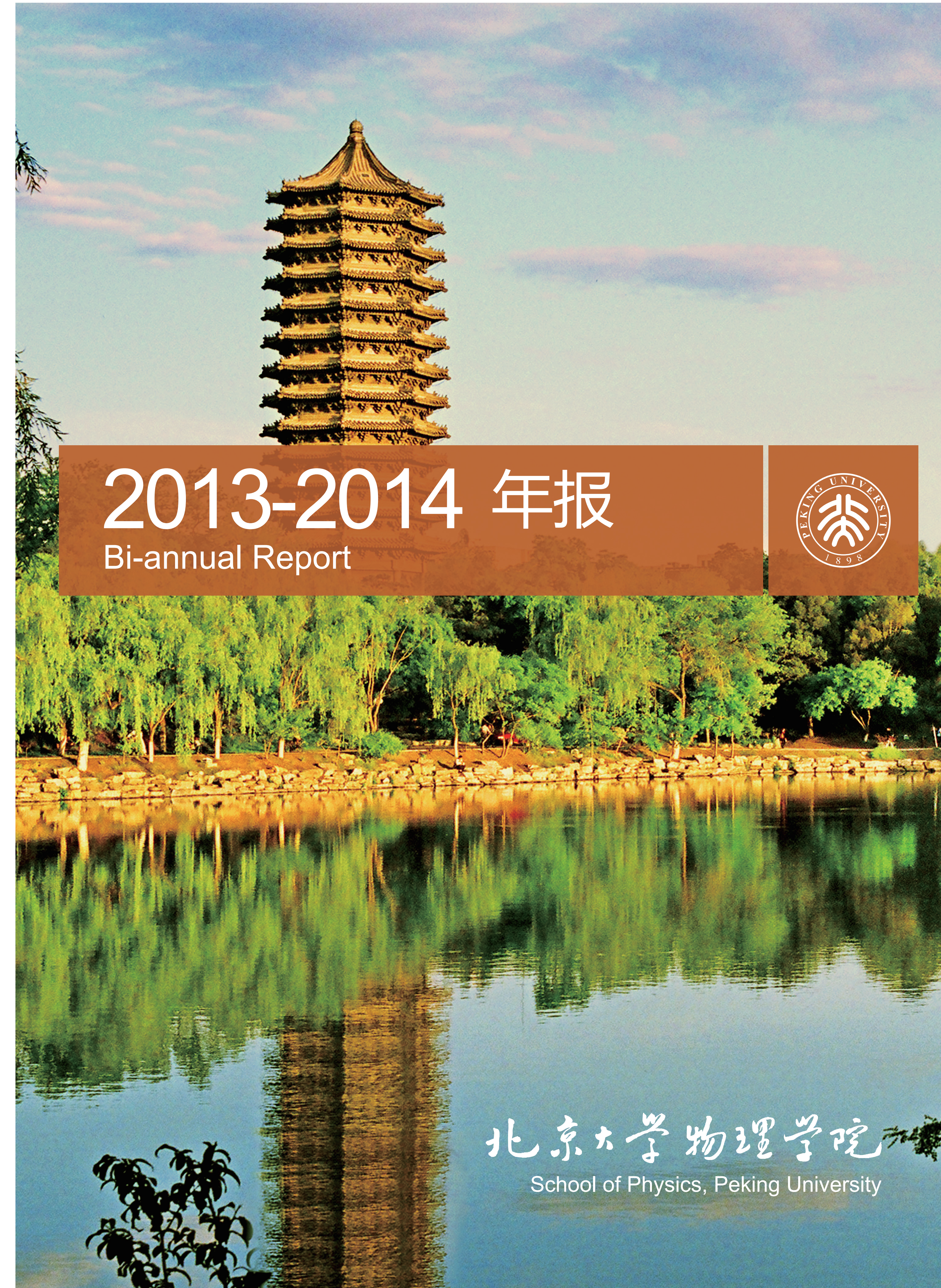
2013-2014 年报 Bi-annual Report



2013-2014 年报

Bi-annual Report

北京大学物理学院

School of Physics, Peking University

前言
The Dean's Address

北京大学是中国近代最早进行物理教育和研究的高等学府。自 1913 年设立物理学门起，北大物理已经走过一个世纪的风雨历程。百年来，我们经历了创业初期的步步艰辛，创造出西南联大时的鼎盛辉煌；既目睹过国家解放后的蓬勃发展，更见证着改革开放以来的巨大进步。几代北大物理学人筚路蓝缕，矢志不移，苦心耕耘，艰难玉成，以自己的远见卓识、坚韧不拔和惟实创新铸就了中国物理乃至中国现代科学教育与研究的根基。时至今日，北京大学物理学院已经发展成为享誉海内外的物理学研究重镇和顶尖人才培养摇篮。

纵观世界一流的物理教育科研机构，无不都有历经久远、点滴积淀的独特传统，引领方向、特色鲜明的目标宗旨，科学合理、规范高效的管理体制，国际顶尖、各有所长的人才群体，宽松自由、协同共进的学术氛围，严谨缜密、执着求真的科学品质，追求卓越、开拓进取的创新精神以及所有这些因素的有机联系与共同作用。站在一个新的历史起点上，北京大学物理学院正向更高、更远的目标不断奋进。

科学研究是物理学院的立院之本。在我对北大，甚至对许多国内外大学的了解中，并不多见一个学院的科学研究领域在空间和时间的尺度上能像我们物理学院这样宽广——大到宇宙与星系，小到原子和夸克；快到阿秒，慢至亿年。北京大学物理学院始终面向国际一流、探索科学前沿；我们既鼓励原创性基础研究，也积极推进具有潜力的应用研究，更提倡不同学科之间的交叉拓展。我们努力寻求和把握物理研究的趋势和方向，期待在未来的竞争和发展中持续突破、有所作为。

物理学院一切工作的中心在于凝聚和培养人才。我们一直致力于发现、吸引、培养和使用具有国际竞争力的拔尖创新人才，他们不仅包括才华横溢的教授学者，还有壮志凌云的青年才俊和莘莘学子。我们为卓越人才全力准备的，不仅是良好的科研条件、完备的基础设施和优厚的生活保障，更在于自由活跃的学术气息、轻松愉悦的人文氛围和广阔持续的发展空间。我们深信，对浩瀚无际的未知世界的痴迷、执着和探求，是每个北大物理学人真正的生命意义与价值所在。

格物致知，薪火相传；百年物理，继往开来。今日的北京大学物理学院，将继续秉承百年来积淀的优良传统，发扬“勤奋、严谨、求实、创新”的卓越精神，脚踏实地、同心同德、积极进取；努力向“将学院建设成为在国内物理学界起到骨干引领和带头示范作用，在国际物理学界具有重要影响的教学科研中心”的目标不断坚实迈进！

谢心澄
北京大学物理学院院长

Peking University is the first institute of higher learning in modern China to conduct physics education and research. It has been over a hundred years since Peking University established its physics division in 1913. One hundred years on, we have experienced the hardships of pioneering, the prime time of the National Southwest Associated University period, the vigorous development at the foundation of the new country, and the huge progress brought by the execution of the Reform and the Opening Up policy. Generations of scholars here have consolidated the foundation for the education and research of physical science and modern science in general in China with their combined vision, perseverance and innovation. Today, Peking University School of Physics has become a highly renowned research and talent cultivation center in physics.

As it embarks on its second century, Peking University School of Physics establishes its new goal of developing into the world's top institution of physics education and academia. In order to achieve this goal, we will carry out our distinguished traditions, identify the specific target purpose, construct a scientific and sustainable mechanism, attract and train the outstanding talent groups, create a free and corporative environment, develop a rigorous and truth-seeking academic attitude, and cultivate an exceeding and innovative scholarly spirit.

The root of our work lies in promoting physics research. Based on my observations of many colleges and universities at home and abroad, there are quite few whose fields of study can be as broad as ours—both spatially and temporally—as big as universes and galaxies, small as atoms and quarks, and as fast as attoseconds, slow as billion years. The research in Peking University School of Physics is not only devoted to the frontiers of fundamental physics but also to the innovation of advanced technology as well as to the exploration of interdisciplinary collaborations.

We strive to follow the development trend of physics research and expect to make continuous breakthroughs in the future.

The center of our work is attracting and cultivating talents. We have been engaging ourselves in discovering, attracting and training leading innovative talents, including distinguished scientists, outstanding young scholars and students. We seek to provide for them favorable research and living conditions, a free and friendly working environment and a sustainable room to develop. It is our belief that the true meaning of our lives here at Peking University School of Physics lies in the infatuated and persistent exploration into the infinite world of the unknown.

Today, Peking University School of Physics will continue to extend its great scholarly tradition of "Diligence, Rigorousness, Truth, and Innovation", make down-to-earth, united and active efforts in order to build the School into a leading institute of physics education and research that not only plays a leading role in China but also exerts an important impact on all over the world.

Xincheng Xie
Dean of School of Physics, Peking University

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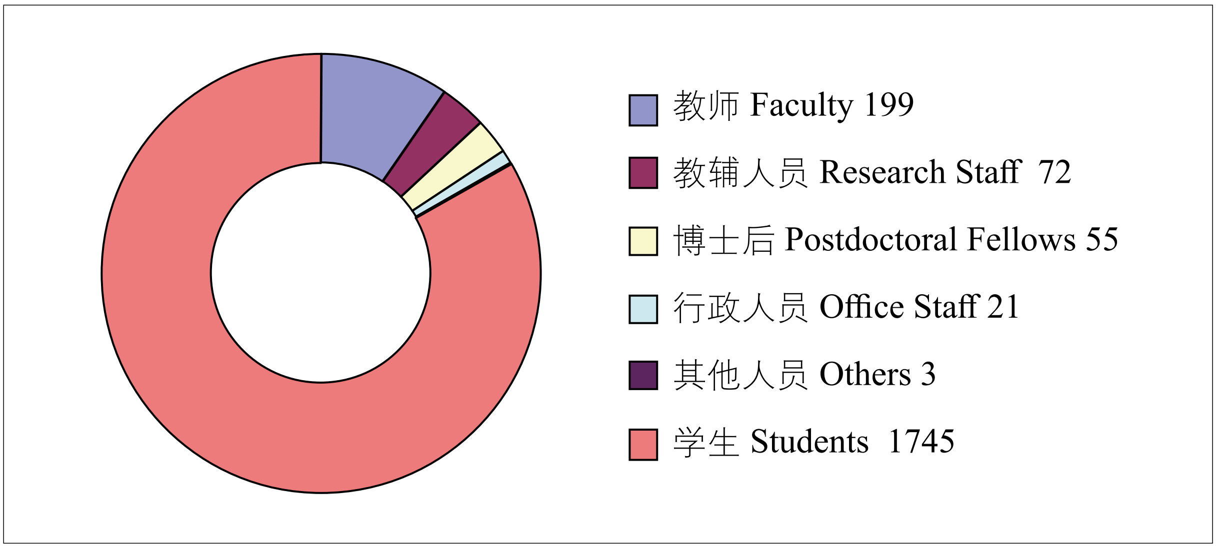

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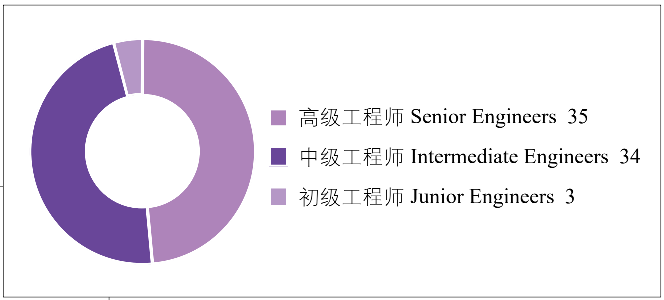

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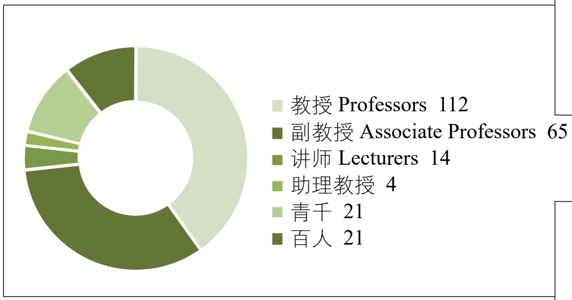

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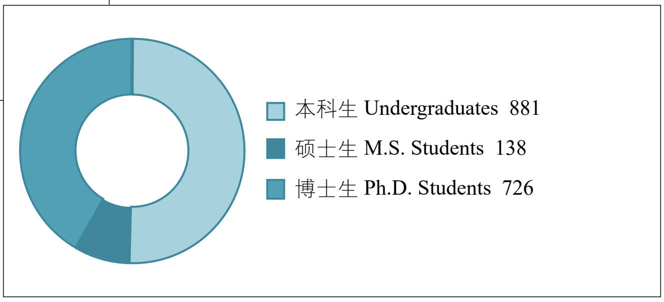

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下属机构
Divisions

- 理论物理研究所 Institute of Theoretical Physics
- 凝聚态物理与材料物理研究所 Institute of Condensed Matter and Material Physics
- 现代光学研究所 Institute of Modern Optics
- 重离子物理研究所 Institute of Heavy Ion Physics
- 等离子体物理与聚变研究所 Institute of Plasma Physics and Fusion Studies
- 技术物理系 Department of Technical Physics
- 天文学系 Department of Astronomy
- 大气与海洋科学系 Department of Atmospheric and Oceanic Sciences
- 普通物理教学中心 Teaching Center for General Physics
- 基础物理实验教学中心 Teaching Center for Experimental Physics
- 电子显微镜专业实验室 Electron Microscopy Laboratory
- 高能物理研究中心 Center of High Energy Physics
- 量子材料科学中心 International Center for Quantum Materials
- 科维理天文与天体物理研究所 Kavli Institute for Astronomy and Astrophysics

系所中心研究亮点
Highlights

01 理论物理所 Institute of theoretical physics

理论物理研究所现有教职工 15 人，其中教授 11 人，副教授 3 人，办公行政 1 人。主要研究领域包括：超弦与宇宙学、粒子物理、强子物理、核物理、凝聚态理论与统计物理等，涉及了自然界从宇观到介观直至微观基本粒子的各个尺度。

There are 15 members in the institute with 11 professors, 3 associate professors and one administrative staff. The research fields include: string and cosmology, particle physics theory, hadronic physics, nuclear physics, condensed matter and statistical physics which cover from the scale of the universe down to microscopic scales of elementary particles.

一、AdS_3/CFT_2 对应中纠缠熵的研究

纠缠熵是量子多体系统中的重要概念，包含着系统的重要信息，如活跃的动力学自由度等。它可以作为凝聚态系统的量子序参量，也可以描述非平衡态。近年来，纠缠熵被应用于引力 / 规范对应的研究中。由于量子场论包含着无穷多自由度，其中纠缠熵的计算是一个非常困难的问题。利用 AdS/CFT 对应，人们提出了引力中全息地计算纠缠熵的方法。全息纠缠熵在引力和量子场论之间搭起了桥梁，帮助我们理解引力的本质，也提供了新的手段来计算量子场论中的纠缠熵。然而全息纠缠熵是否严格等价于场论中的纠缠熵是一个没有完全解决的问题。2013 年春，人们发现在 AdS_3/CFT_2 对应中，全息纠缠熵的经典部分与共形场论场论中的纠缠熵的领头阶是一致的。此时，AdS_3 中的量子引力与一个具有大中心荷的共形场论等价，场论的大中心荷展开等价于引力中耦合常数的展开。因此，场论中的大中心荷展开下次领头阶贡献应该与全息纠缠熵的单圈量子修正对应。如何定量地验证这一对应是全息纠缠熵领域中面临的重要问题。理论物理所的陈斌教授领导的研究组仔细研究了此类共形场论中双间隔情形（JHEP 1311 (2013) 16）以及有限温度单间隔情形（JHEP 1408, 032 (2014)）下的纠缠熵，发现在此两种情形下场论计算得到的 Renyi 熵在次领头阶与引力计算的结果高度一致。这些研究强有力地支持了在 AdS_3/CFT_2 对应中引力全息计算的正确性，为进一步理解纠缠熵和全息原理提供了方向。这些工作获得了很好的国际关注和好评，陈斌教授先后受邀在“Solvay workshop on Holography for Black holes and Cosmology”以及“International workshop for String theory and cosmology”等国际研讨会上介绍这些工作。

进一步地，陈斌研究组把这些对纠缠熵研究推广到有 W- 对称性的共形场论（JHEP 1404 (2014) 041）、对数共形场论（JHEP 1403 (2014) 137）及其对偶的量子引力的研究中。最近，该研究组深入研究了在高温下大间隔情形下的纠缠熵并证明了对于有离散谱的共形场论热力学熵与纠缠熵间的普适关系。

I. Entanglement entropy in AdS_3/CFT_2 correspondence

Entanglement entropy is an important notion in quantum many body system, encoding the valuable information of the system, for example the active degrees of freedom. It may be used to be the quantum order parameter in condensed matter system, to characterize non-equilibrium states. In recent years, the entanglement entropy has been studied in the context of AdS/CFT correspondence. Due to infinite degrees of freedom in a field theory, it is very difficult to compute the entanglement entropy in a quantum field theory. People proposed a holographic way to compute such entropy in classical gravity. This holographic entanglement entropy(HEE) set up a bridge between gravity and quantum field theory. It not just provides a new computing tool, but also helps us to understand the nature of gravity. One central question about holographic entanglement entropy is to what extend it equals the entanglement entropy in field theory. In the spring of 2013, it was proved that the holographic computation of the entanglement entropy is correct at the leading order in the context of AdS_3/CFT_2 correspondence. In the case, the quantum gravity in AdS_3 is equivalent to a kind of conformal field theory(CFT) with certain central charge. As the central charge is inversely proportional to the gravitational coupling constant, the large central charge limit in the field theory corresponds to the weak coupling limit in gravity. Therefore, the subleading contribution in CFT should correspond to 1-loop quantum correction to the HEE. It is an important question to study the HEE in the subleading order. Prof. Bin Chen in ITP and his collaborators discussed the entanglement entropy of two-interval （JHEP 1311 (2013) 16）and single interval at finite temperature case (JHEP 1408, 032 (2014)). They found that in the large central charge limit, the field theory results are in exact agreements with the holographic computation in both the leading and subleading orders. These studies provide very strong support to the holographic computation, and open a new window to investigate the entanglement entropy and holographic principle.

Furthermore, the group extended the study on the entanglement entropy to the CFT with W symmetry (JHEP 1404 (2014) 041) and logarithmic CFT(JHEP 1403 (2014) 137) , and obtained good agreements with the HEE in the dual quantum gravities. Very recently, the group investigated the large interval entanglment entropy of 2D CFT at high temperature, and proved an universal relation between thermal entropy and entanglement entropy for a CFT with discrete spectrum.

二、顶夸克的产生和衰变中量子色动力学效应的新进展

顶夸克事例正被位于欧洲的大型强子对撞机（LHC）上的实验家们大量观测到。随着 LHC 亮度的增加，顶夸克的各种性质将被实验家们更加精确地测量，这对于检验标准模型和探索超出标准模型以外的新物理非常重要。因此要求理论家对顶夸克在强子对撞机上的产生和衰变过程做出量子色动力学（QCD）的更加精确的理论预言，　而这也是国际高能物理界公认的难点问题。最近，李重生课题组和杨李林课题组在这一问题上取得重大突破，在《物理评论快报》上连

续发表两篇论文。

对于顶夸克产生这类具有复杂色结构的过程，在量子色动力学中进行横向动量重求和一直有一个悬而未决的难点，即对初态与末态之间色干涉效应的处理。李重 生课题组和杨李林课题组最近合作发表在物理评论快报(Physical Review Letters, 110, 082001, 2013）的工作首次发展了一个系统的框架，可用来计算这类末态带色过程中横向动量重求和的效应，并进而将这种方法应 用于顶夸克对产生过程，对其横向动量分布给出了目前文献中最精确的量子色动力学预言。这些精确理论预言有助于解释最近在 Tevatron 对撞机上所观测到的顶夸克对产生中前后不对称性的实验结果与标准模型理论预言有较大偏离的可能起源。同时，对未来在 LHC 上通过测量顶夸克对不变质量分布来发现新物理信号也很重要。此外，上述横向动量重求和形式还为计算顶夸克对产生的次次领头阶 QCD 修正提供了一种新的红外发散减除方法，这将有助于完整计算顶夸克对产 生的次次领头阶 QCD 修正，而后者正是当前 LHC 实验所急需的，也是量子色动力学中一个亟待解决的问题。这个工作已被《亚太地区物理通讯》列为“研究亮点”（Research Highlights）工作报道，并被 LHC 上 ATLAS 实验组的实验结果所检验。在该项研究中，李重 生教授指导的博士研究生朱华星（现美国斯坦福大学国家加速器实验室博士后）、李海涛、邵鼎煜（现瑞士伯尔尼大学博士后）发挥了重要作用。

如何在 QCD 次次领头阶水平上计算顶夸克微分衰变率是国际上近 20 年来一直没有解决的问题。李重 生教授和已毕业的博士生，现美国 Southern Methodist 大学博士后高俊以及美国斯坦福大学国家加速器实验室博士后朱华星合作，基于 QCD 软共线有效理论，提出了消除相空间红外发散的新方法，从而在国际上首次给出 QCD 次次领头阶水平上顶夸克衰变中包括微分衰变率在内的所有观测量的完整预言。这个工作发表在《物理评论快报》（Physical Review Letters, 110, 042001, 2013）上，被国际著名 QCD 专家、欧洲核子联合研究中心理论部的 Alexander Mitov 在最近召开的国际学术会议上评价为：“它打开了一扇通向在 QCD 次次领头阶水平上精确预言顶夸克产生和衰变的大门”。最近在美国召开的 Snowmass 2013 会议上，美国 M. Schulze 等三位粒子物理学家在他们的联合综述中引用了上述两个工作，其中专门用了一页的篇幅介绍李重生课题组有关顶夸克微分衰变率的工作。

II. Recent progresses on the quantum chromodynamics effects in the production and decay of the top quark

Top quarks are produced in abundance at the CERN Large Hadron Collider (LHC). With the increasing integrated luminosity collected at the LHC, the properties of the top quark will be measured with higher and higher precision, which are very important to test the Standard Model and search for new physics beyond it. Therefore, it is necessary to make accurate theoretical predictions for top quark production and decay at hadron colliders, which is regarded by international theoretical physicists as a very difficult problem. Recently, Prof. Chong Sheng Li’s group and Prof. Li Lin Yang’s group have made significant progress on this problem, and have published two papers in Physics Review Letters.

For processes with complicated color structure, such as top quark production, there is a longstanding difficulty in performing transverse momentum resummation. That is the treatment of the color interference among the initial states and the final states. Recently, Prof. Chong Sheng Li’ s group and Prof. Li Lin Yang’ s group jointly developed a systematic framework to perform transverse momentum resummation in any process, and applied this method for top quark pair production. This work was published in Physics Review Letters, 110, 082001 (2013), which gives the most accurate QCD prediction for the transverse momentum distribution of top quark pairs. These results helps to explain the discrepancy between theory and experiment on the forwardbackward asymmetry in top quark pair production. Meanwhile, the new framework provides a new infrared subtraction method to compute the next-to-next-to-leading order (NNLO) QCD effects in top quark pair production, which are eagerly demanded by LHC experimentalists. This work was reported as a research highlights in Asia Pacific Physics Newsletter, and has been verified by the experimental results of the ATLAS collaboration at the LHC. The students of Prof. Chong Sheng Li: Hua Xing Zhu (now a postdoc at Stanford Linear Accelerator Center), Hai Tao Li and Ding Yu Shao (now a postdoc at University of Bern) played an important role in this research.

How to calculated the fully differential decay rate of the top quark at NNLO in QCD was an unsettled problem in recent 20 years. Based on the soft-collinear effective theory, Prof. Chong Sheng Li and his former students, Jun Gao (now a postdoc at Southern Methodist University) and Hua Xing Zhu (now a postdoc at Stanford Linear Accelerator Center), proposed a new infrared subtraction method, and calculated for the first time all differential observables in top quark decay at NNLO in QCD. This work was published in Physical Review Letters, 110, 042001 (2013), and was quoted by Alexander Mitov (a leading international QCD expert at CERN) as “opening the door for future fully differential NNLO calculations of top pair production and decay”. In the report of Snowmass 2013, 3 physicists including M. Schulze quoted both of the above works and especially, described the work on top quark decay using one page.

02 凝聚态物理与材料物理研究所
Institute of Condensed matter and Material Physics

凝聚态物理与材料物理研究所现有教职工 59 人，其中，教授 18 人，副教授 20 人，工程技术人员 14 人，青千研究员 3 人，百人计划研究员 4 人。 研究队伍中包括，院士 4 人，长江特聘教授 4 人，国家杰出青年 5 人。 研究领域包括宽禁带半导体物理和器件，凝聚态理论，纳米半导体与半导体光子学，表面物理与扫描探针显微学，高温超导体及其相关材料、物理与器件，纳米结构和低维物理，软凝聚态物理，以及磁性物理和新型磁性材料。

There are 59 faculty members in the institute, consisting of 18 full professors, 20 associate professors, 14 engineering technicians, 3 Qingqian professors and 4 Bairen professors. Among the senior researchers are 4 academicians of the CAS, 4 Chang Jiang scholar professors，and 5 national distinguished young scholars. The research fields covering a wide range include Devices and Physics of Wide-gap semiconductors, Condensed Matter Physics, Nanosized Semiconductors and Optoelectronic Physics, Surface physics and Scanning Tunneling microscopy, Physics and Devices of High Temperature Superconductors, Low-dimension Nanostructure and Physics, Soft Condensed Matter Physics, and Physics of Magnetism and Advanced Magnetic Materials.

一、第一性原理核量子效应模拟方法的发展及其在氢相图研究中的应用

材料性质的第一性原理理论模拟，依据玻恩 - 奥本海默近似，需要人们对电子结构与原子核运动都给出准确的描述。目前电子结构的计算已相对成熟，针对同一体系，很多方法都能在量子力学的层面给出相当精准的结果，但原子核运动的描述却往往上停留在经典力学的层面。越来越多的研究表明，原子核的量子属性可对物性产生重要影响。因此发展一个完善的核量子效应模拟方法并且将其同各种分子模拟手段结合，已成为分子模拟领域的一个前沿。

具体到相图研究，将上述手段引入也是一直以来的一个热点，其中的典型代表就是高压下氢相图。自 1935 年 Wigner 与 Huntington (J. Chem. Phys. 3, 764,(1935)) 提出金属氢的假说，这个问题一直被誉为高压物理研究的圣杯，但在压强超过 300 GPa 时，人们目前的认识还很不完善。实验上的局限主要是因为达到如此大的压强很难，同时氢对电子和X光等常见探测手段的散射截面也很小。而理论上，人们需要同时在很多方面进行精细的处理，如：1) 电子结构，2) 高维玻恩 - 奥本海默势能面的搜寻，3) 核量子效应的描述，4) 滞后效应的去除。

这项工作中，我们从理论模拟角度对这些方面都进行了精细的处理。图 1 显示的是我们的相图，插图是计算细节。其中，上（下）三角对应在是两相模拟中系统凝固（熔化）的最高（低）温度。利用该技术，我们可以将相变温度缩小到一个很小的范围，从而尽量去除滞后效应的影响。插图同时对比了基于第一性原理电子结构计算的分子动力学模拟（原子核为经典粒子）与路径积分分子动力学模拟（原子核为量子）的计算结果，分别由红线与黑线标记。通过对比，我们可以清楚地看到模拟得到的低温液体为核量子效应诱发。

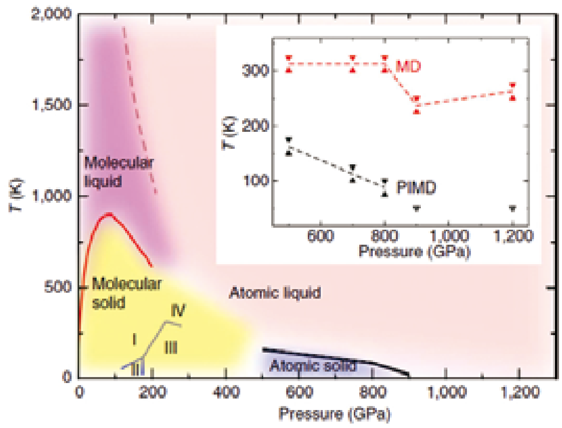


图 1：高压下的氢相图，以及经典（量子）统计下固体氢的熔化曲线。

Fig. 1: Phase diagram of dense hydrogen under pressure, the black solid line is the melting curve we established in our study.

此外，前人的研究工作还预测，高压下固体氢的金属相可能会有较高的超导转变温度 (Tc)。基于 Allen-Dynes 方程，我们的计算表明在 500 GPa 下 Tc 可高达 358K。但需要注意的是在如此高压下，固体氢的超导转变温度已高于熔点。因此，单纯依赖简谐近似得到的 Tc 是不可靠的，因为它依赖于固体晶格的稳定存在。在引入真实非简谐项之后，固体在这个室温已经熔化。而另一方面，既然 Tc 高于熔化温度，那固体只要存在系统就应该在 BCS 理论的框架下超导。

结合以上两点，这个熔化曲线应该是介于一个全超导的固态和一个由核量子效应诱发的低温液态之间的。这项工作发表于 Nature Communications 4, 2064 (2013)。第一作者陈基为物理学院 09 级博士研究生，北京大学物理学院凝聚态所的李新征研究员是工作的主要设计者，该研究得到了国家自然科学基金，国家科技部的支持。

I. First-principle simulations of nuclear quantum effects and a discovery of low-temperature metallic liquid hydrogen.

Theoretical descriptions of material properties, according to the Born-Oppenheimer approximation, can be separated into two main tasks: an accurate ab-initio description of the electronic structures and a proper treatment of the nuclei's propagation on the corresponding potential energy surfaces (PESs). Currently as one of the most powerful methods on fulfilling such tasks, standard ab-initio molecular dynamics (MD) addresses the electronic states well in many cases. The treatment of the nuclei's propagation, however, still stays at the level of the classical mechanics. It is well-known that for light elements like hydrogen, when the distance between the two classical PES minima of one nucleus is short enough to be comparable to the nuclear de Broglie wavelength, the nuclear quantum effects (NQEs) can be really important. Properly describing phenomena like these requires a fully quantum treatment of both the electrons and the nuclei. The corresponding method development on this direction, accordingly, becomes a focus of recent theoretical studies.

Besides the importance of method development, the nature of dense hydrogen is also a central problem in physics. Its abundance in, for example, gas giants such as Jupiter and Saturn, means that it is critical to our understanding of the universe. In spite of the tremendous progress made over the last 80 years, important gaps in our understanding of the hydrogen phase diagram remain, with arguably the most challenging issue being the solid to liquid melting transition at ultra-high pressures. These gaps exist for several reasons. From the experimental perspective, achieving such high pressure and combining it with different detecting techniques is difficult, plus the scattering cross-sections of hydrogen to electrons and X-ray are small. From the theoretical perspective, accurate descriptions of such system require several aspects of the simulation to be delicated addressed, e.g. accurate electronic structures, complete exploration of the high-dimensional PES, inclusion of the NQEs, and minimization of the hysteresis effects.

In this work, using a combination of ab initio path-integral molecular dynamics (PIMD), ab initio random structure searching, and two-phase simulation techniques, we carried out a systematic theoretical research on understanding the phase diagram of dense hydrogen. The main results are shown in Fig. 1. The inset shows our simulation details. By comparing the melting curves obtained using MD (with classical nuclei, data in red) and PIMD (with quantum nuclei, data in black), it is clear that there is a low-temperature liquid phase, which originates from the NQEs. Electronic structure calculations of this liquid phase show it is metallic.

Besides this, several earlier studies show that the solid phase below the melting curve is superconductor with transition temperature (Tc) higher than 300 K. Using Allen-Dynes equation, we easily reproduce such results. However, we note that these results rely on the harmonic approximation. From our simulations of the melting, we understand that the solid phase melts well below 300 K. Therefore, such estimations of Tc based on the harmonic approximation tends to be optimistic in nature. On the other hand, since this Tc is higher than the melting temperature, it also indicates that as long as the solid exist, it should be a superconductor. The melting curve, consequently, exists between a superconducting solid and a low-temperature metallic liquid.

This work was published on Nature Communications

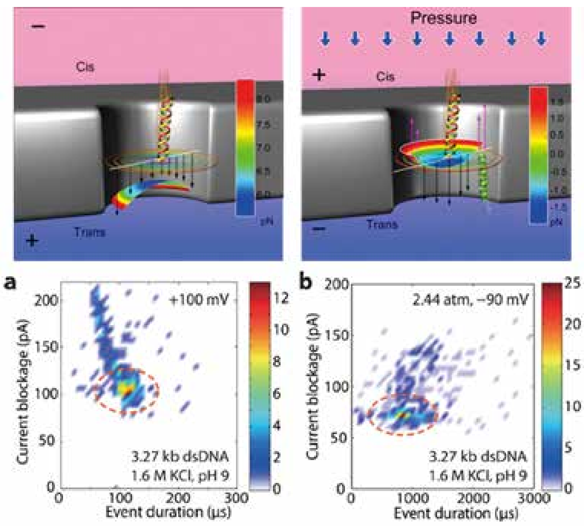
4, 2064 (2013). Ji Chen, a Ph.D student of our school, is the first author. Prof. Xinzheng Li is the chief designer. This research is partially supported by the NSF of China and the MOST of China.

二、利用固体纳米孔显微镜 (Solid-State-Nanopore Microscope) 进行 DNA 单分子的可控检测

纳米孔 DNA 测序技术被认为是实现第三代快速，低成本，长链直读 DNA 分子测序最有竞争力的技术之一，对研究人类遗传病因，个性化医疗等诸多领域具有非常重大的意义。当溶液中的长链 DNA 分子在电场驱动下穿过一个尺度在纳米量级的小孔时，离子电流会由于 DNA 分子的阻塞作用形成瞬时下降，而对于电流下降的分析可以得知穿孔分子的尺寸，大小，构型等生物学特征。目前固态纳米孔测序领域面临的最大挑战是纳米孔器件承载膜太厚（空间分辨率）和 DNA 分子穿孔太快（时间分辨率）两大国际难题。

凝聚态所俞大鹏团队的赵清副教授，紧紧围绕该领域内的两大国际性难题展开研究，取得了一系列重要研究进展。他们创造性地将压强作为新的驱动力引入到纳米孔中，利用电场作为反向阻力和提取电流信号的载体，通过压强与电场的双场调制，大幅降低了驱动力，有效减慢 DNA 穿孔速度 1-3 个数量级，并保持了很高的测量信噪比和捕捉率，逼近测序所需要求，为该领域内又一大突破性进展。在此基础上，他们大幅拓展了探测链长，实现了对短链分子（600 bp）探测，在固态纳米孔中首次实现了对不同长度 DNA 分子（长度差仅为 600 bp）的有效区分，并且实现了近中性分子（PEG）的单分子探测，较之前报道大大扩展了可探测分子范围。相关结果发表在 Nano Letters 13, 3048 (2013) 上。

在提高纳米孔 DNA 探测空间分辨率上， 赵清副教授经过近 4 年的不断积累，在这一领域取得重要进展。他们在国际上首次利用高质量的双层 BN 纳米孔器件，实现了对双链 DNA 的单分子探测。实验结果表明 BN 纳米孔具备比传统 SiN 纳米孔更高的探测灵敏度。实验和模拟结果均表明，BN 纳米孔的膜厚只有 1.1 纳米，已达到目前国际纳米孔单分子探测领域的最高空间分辨率，成为非常有希望实现第三代 DNA 测序的关键材料之一。相应结果发表在 Advanced Materials 25, 4549 (2013).



图：上图：有无压强引入对 DNA 在纳米孔中受力的影响。下图：DNA 在有无压强存在条件下的穿孔过程的电流与穿孔时间关系图。

Figure upper: effective driving force simulation on DNA inside nanopores. Lower: Current blockage versus event duration of DNA translocation with or without pressure inside nanopore.

II. Single DNA detection/sequencing via Solid-State-Nanopore Microscope

Nanopore-based DNA sequencing is considered to be the most active and potential candidate for next generation fast and low-cost gene sequencing technique. It features many advantages such as label-free, amplification-free, low reagent-volume, long read length, single-molecule approach, and high throughput DNA analysis, which aims to fulfill person gene sequencing within 24 hours under cost below 1000 US dollars. When DNA molecule in solution is electrophoretically driven through a nanopore which separates two chambers with conductive electrolyte under an applied voltage, the ionic current through the nanopore is partially blocked by the passing molecule. The modulation of the current reveals useful information of the structure and dynamic motion of the molecule.

One of the main challenges remained in solid-state nanopore based sequencing field is the membrane containing nanopore is too thick (usually >20nm for conventional SiN nanopores) to reach single base discrimination resolution. Except graphene, few kinds of solid-state pores have capability in achieving enough high spatial resolution in DNA sequencing. BN has low dielectric constant, high mechanical strength, large thermal conductivity, and high corrosion resistance. Moreover, the thickness of a single layer BN is comparable to the spacing between nucleotides in ssDNA (0.34 nm), which makes it a competitive candidate to realize single-base resolution on superthin nanopore structures.

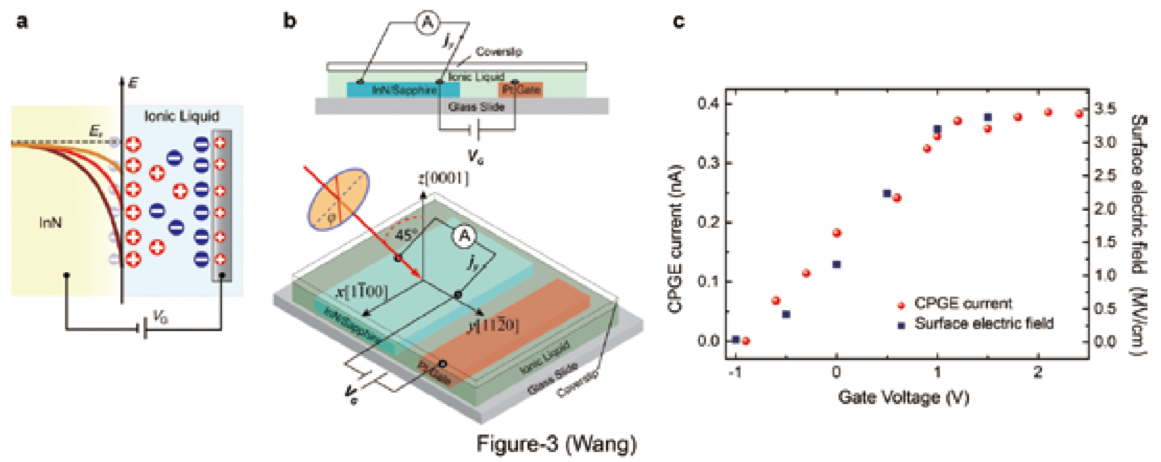
A nanopore group led by Prof. Qing Zhao and Prof. Dapeng Yu in Peking University has achieved progress in this field recently. By using a controllable transfer technique, they successfully fabricated size tunable BN nanopore devices and demonstrated the first report of DNA translocation through BN nanopores: double-stranded DNA molecules were successfully translocated through high quality two- or three-layer BN nanopores. The BN nanopores showed much higher sensitivity in DNA single-molecule detection compared with SiN nanopores. The effective thickness of BN is around 1.1 nm, from TEM analyses and numerical simulations, indicating BN has reached the best spatial resolution of graphene, which provides another competitive candidate for DNA sequencing. The ultrathin BN nanopores provide substantial opportunities in realizing high spatial sensitivity nanopore device for various applications. The results have been published in Advanced Materials 25, 4549 (2013).

三、In(Ga)N 的分子束外延生长及其原子电子调控

铟镓氮（InGaN）半导体材料的禁带宽度可在 3.39-0.64 电子伏特之间连续可调，波长涵盖了紫外到红外的宽波段，可实现多波段可调的光电器件。但是 InN 的外延生长极为困难，直接导致高 In 组分 InGaN 材料外延的困难，从而限制了 InGaN（特别是高 In 组分 InGaN）在器件上的应用。从发展趋势上看，器件级 InN 材料是长期解决问题的根源所在，而高 In 组分 InGaN 量子结构的研究有助于尽快实现器件，为应用提供基础，因此需要两方面齐头并进，以期早日实现突破。物理学院宽禁带半导体研究中心王新强和沈波教授研究组，采用分子束外延生长方法，深入研究了晶体极性

控制外延生长机制，探讨了 InN 薄膜中的载流子散射机制，针对 InN 外延的难点，提出了临界温度外延的方法，有效提升了晶体质量，控制了 InN 中位错和点缺陷密度，2012 年将 InN 薄膜的室温电子迁移率提升到 3280 cm2/Vs，2013 年室温电子迁移率超过 3500 cm2/Vs。研究了 InN 的 p 型掺杂及 InN 的光电导效应，解释了 InN 负光电导效应的物理机制，提出了一种利用光电导效应判断 InN 掺杂极性反转的新方法 [Scientific Reports, 4, 4371 (2014)]。研究了 InGaN 合金和数字合金的外延生长及其 In(Ga)N 超薄层的控制，利用生长温度控制外延实现了较高质量的全 In 组分可调 InGaN 材料。深入研究了 InN 和 InGaN 单原子层的外延控制，实现了单原子层 InN 和 InGaN 量子结构，利用分子束外延技术实现了单原子层 InGaN 中 In 原子和 Ga 原子的规则排列。

在优化生长的基础上，利用离子液体栅在掺镁 InN 和非掺杂样品上制作了电子双层晶体管，在掺镁 InN 样品中观察到反常的霍尔系数随栅压的曲线振荡，证明了 InN 的埋层 p 型电导。基于 Rashba 自旋轨道耦合效应的电子自旋调制是自旋电子学应用的重要一环，而 InN 的表面二维电子气系统为自选轨道耦合效应提供了一个天然的平台。利用液体栅调制了 InN 表面电子的自旋轨道耦合，通过圆偏振光电流效应的测试结果得到很好的证实（如图一所示），从而提供了一条可能实现表面自旋注入的途径 [Nano Letters 13, 2024 (2013)]。将 InN 表面的研究拓展到 WSe2 材料，和斯坦福大学合作，同样观察到可调制的圆偏振光电流 [Nature Nanotechnology 9, 851, (2014)]。相关研究工作得到了国家自然科学基金、科技部和人工微结构和介观物理国家重点实验室的支持。



图一、液体栅调控下的圆偏振光电流效应测试：（a）液体栅调控电子双层晶体管及其能带调制示意图，（b）液体栅调控电子双层晶体管下圆偏振光电流效应测试示意图，（c）表面电场调制下由表面电子导致的圆偏振光电流随外加栅压的变化曲线。

Figure 1. CPGE measurement with ionic liquid gating. (a) The schematic diagram of the ionic liquid gating EDL transistor and resulting modification of interfacial band bending. (b) The cross-section and oblique drawing diagrams for the modulation of the CPGE with ionic liquid gating EDL transistor. (c) The CPGE current contributed by surface electrons and the surface electric field, as a function of applied gate voltage.

III. In(Ga)N:Molecular beam epitaxy and atom/electron manipulation

InGaN compound semiconductor, with a continuous tunability of bandgap energy from 3.39 to 0.64 eV, covers a broad wavelength from ultraviolet to infrared and thus makes it possible to realize the optoelectronic devices with tunable wavelengths. Unfortunately, the epitaxy of InN is extremely difficult, which leads to the difficulty of epitaxy of InGaN, in particular that with high In composition. This definitely limits its application in devices. In principle, people should sovle the growth difficulty and achieve InN material satisfying the devices requirements, which definitely needs long-time effort. On the other hand, the growth of quantum structures such as In(Ga)N quantum wells with relatively high In content is somehow easier and can be used for devices much earlier. Therefore, both aspects should be concentrated on for nitrides researchers in order to fabricate In(Ga)N-based devices. Wang and Shen's group at Research Center for Widegap Semiconductors in School of Physics, has deeply studied the lattice-polarity-controlled epitaxy of InN by molecular beam epitaxy and investigated the carrier scattering mechanism in InN layers. They proposed a novel boundary-controlled-epitaxy method and improved the crystalline quality of InN. The density of threading dislocations and point defects was reduced, which leads to a record room temperature electron mobility of 3280 cm2/Vs at InN layer in 2012. This value was upgraded to more than 3500 cm2/Vs in 2013. The group further studied the p-type doping effect and the photoconductivity of InN, clarified the usual negative photoconductivity in InN and then proposed a new way to confirm the conduction polarity conversion by using photoconductivity effect [Scientific Reports, 4, 4371 (2014)]. The group also studied the epitaxy of InGaN alloys and digital alloys, paying attention to the control of the ultrathin In(Ga) N layer. Finally, they achieved the quantum structures with one atomic layer InN and InGaN wells. In particular, the in-plane ordered arrangement of In and Ga atoms was achieved.

Taking advantages of broad tunability of carrier density in electric-double-layer transistors (EDLTs) with ionic-liquid gating, they demonstrated the evidence of parallel conduction from both p-type bulk and n-type surface in Mg-doped InN EDLTs. Large anomalous oscillation in Hall coefficients with decreasing gate bias was observed in Mg-doped samples, providing the proof for the p-type bulk conduction in Mg-doped InN. Electrically manipulating electron spins based on Rashba spin orbit coupling (SOC) is a key pathway for applications of spintronics. Two-dimensional electron systems (2DESs) offer a particularly important SOC platform, where spin polarization can be tuned with an electric field perpendicular to the 2DES. By measuring the tunable circular photogalvanic effect (CPGE), they presented an electric-field modulated spin splitting of surface electrons on InN thin films that is a good candidate to realize spin injection [Nano Letters 13, 2024 (2013)]. The clear gate voltage dependence of CPGE current indicates that the spin splitting of the surface electron accumulation layer is effectively tuned, providing a way to modulate the injected spin polarization in potential spintronic devices. The study on surface electron manipulation has been extended to the WSe2. In collaboration with Cui's group at Stanford University, a spin-coupled valley photocurrent, within an electric-double-layer transistor based on WSe2, was successfully observed [Nature Nanotechnology 9, 851, (2014)]. This research work is partially supported by the NSFC, the MOST of China and the State Key Laboratory of Artificial Microstructure and Mesoscopic Physics.

03 现代光学研究所 Institute of Modern Optics

现代光学所以教师队伍建设为核心，通过培养和引进优秀青年学者，十多年来发展迅速。现有教职员工 24 人，其中教授 9 人，“百人计划”研究员 6 人，副教授 5 人，高级工程师 1 人，工程师 3 人，以及博士后 2 人，在读博士、硕士研究生近百人。有 1 位中科院院士，2 位长江特聘教授， 2 位国家 973 和国家重大科学研究计划项目首席科学家， 3 位国家自然科学基金委杰出青年基金获得者，4 位国家自然科学基金委优秀青年基金获得者。1 人入选万人计划，1 人入选青年千人计划，7 人入选教育部新世纪优秀人才支持计划，1 人入选北京市科技新星计划。2006-2014 年龚旗煌教授领导的“介观光学与飞秒光物理”团队连续 3 次获得国家自然科学基金委创新研究群体滚动资助。现代光学所教员担任 Optics Letters、Chemical Physics Letters、Opt. Commun.、Adv. Opt. Mater.、Chemical Physics 等国外重要杂志编委以及《中国科学 G》，Chin. Opt. Lett.， Chin. Phys. B 和《物理学报》等多个国内刊物副主编；当选美国光学学会 (OSA) Fellow 和英国物理学会（IoP） Fellow，兼任 OSA 计划委员会委员、中国光学学会副理事长、秘书长和副秘书长等职。

2014 年龚旗煌带领的“极端光学”团队入选科技部重点领域创新团队，刘运全受聘教育部长江特聘教授并入选科技部创新人才计划。肖云峰研究员和龚旗煌院士主持的项目“单个纳米颗粒光学检测新原理研究”入选“2014 年度中国高等学校十大科技进展”。2014 年，李焱、杨宏和蒋红兵等人研究项目“飞秒激光三维微纳制备机理及其应用基础研究”获得中国高校自然科学二等奖。

现代光学所站在国际科学研究前沿，开拓新的光学研究领域，已形成飞秒科学与强场光物理、介观光学与纳微光子学、光电功能器件与量子信息等主要研究方向，在国内外的影响力日益增加，已经逐步成为具有国际竞争力的光学科研和教学重要基地。

The Institute of Modern Optics (IMO) is one of the major research centers in the School of Physics at Peking University (PKU). It was established in May 2001 when the School of Physics was formed. The present director is Professor Qihuang Gong, who is an academician of the Chinese Academy of Sciences (CAS). Historically, Professor Yutai Rao and Professor Ta-You Wu initiated research of modern optics at PKU in the 1930s and developed it into a comprehensive optics program. At present, the optics program at IMO is a National Key Discipline. IMO constitutes one of the two research branches in the State Key Laboratory for Artificial Microstructure and Mesoscopic Physics. IMO has also established several joint research initiatives such as the CAS-PKU Ultrafast Optics & Laser Physics Center and PKU Opto-Electronics Center.

Currently, IMO has 24 faculty members, including 9 professors, 6 “PKU Talent-100” tenure-tracking faculties, 5 associate professors, 1 senior engineers and 3 engineers. The total number of postdocs and graduate students is around 100. Many faculties have received great recognitions in their research fields and attracted prestigious funding from different agencies. Professor Qihuang Gong was elected as Academician of CAS in 2013. He also serves as vice president and secretary-general of the Chinese Optical Society. He is Fellow of both Optical Society of America (OSA) and Institute of Physics (IoP). There are 2 chief scientists of 973 projects and 2

Cheung Kong Scholar professors in IMO. 3 faculties won the National Science Foundation of China (NSFC) support for Distinguished Young Scholars and 4 others won the Excellent Young Scholars from NSFC. There are totally 7 faculties elected into the Program for New Century Excellent Talents in University from the Ministry of Education of China. The group led by Professor Gong won a 9-year continuous support over 2006-2014 under the Foundation for Innovative Research Groups of the NSFC. Many of our faculties serve as editorial members or topical editors for important journals such as Optics Letters、Chemical Physics Letters、Opt. Commun.、Adv. Opt. Mater.、Chemical Physics, and etc. Some of them serve as associate editors in the Science in China Series G, Chin. Opt. Lett., Chin. Phys. B, and Acta Physica Sinica.

In 2014, the “Extreme Optics Research Group” led by Professor Qihuang Gong was awarded the Foundation for Innovative Research Groups from the Ministry of Science and Technology of China (MOST). Professor Yunquan Liu was appointed Cheung Kong Scholar by Ministry of Education of China and selected into“Creative Talent Program” sponsored by MOST. Research achievements in the project of “Study on new principle of optical detection of single nano-particle” carried by Professor Qihuang Gong and Yunfeng Xiao’s groups have been selected as one of“Top Ten Progresses in University Research of China in 2014”. The project of“Research on mechanism and application of femto-second laser 3D fabrication” carried by Professor Yan Li, Hong Yang, Hongbin Jiang and Qihuang Gong won the second prize of High Education Natural Science Award of China.

Since inception, IMO has committed itself to explore new frontiers in optics and tackle global challenges in optical science. The institute has established well recognized research directions including femto-science and intense optical physics, mesoscopic optics and nano-photonics, functional opto-electronic devices and quantum information. With its increasing impact in global optical society, IMO has become globally competitive institute for research and education in optical science.

一、量子轨迹蒙特卡罗理论

原子分子的多光子电离和隧道电离一直是强场光物理的研究前沿，在原子分子结构成像、量子调控等方面具有重要应用。人们对多光子电离的认识一般是通过量子理论，但量子理论是基于波函数和薛定谔方程 , 所得到模拟结果是物理上“不透明的”(not physically transparent)，人们很难直接实现电子的动力学分析。刘运全研究员、彭良友副教授和龚旗煌教授等发展了一套量子轨迹蒙特卡罗 (Quantum-Trajectory Monte Carlo-QTMC) 理论。他们通过蒙特卡罗模拟，把隧道电离理论和费曼路径积分相结合（如图 1a），获得了原子多光子电离全微分光电子角分布的干涉物理起源（如图 1c,d）。在实验上，他们通过新建成的冷靶电子离子动量谱仪，测量了高分辨氙原子多光子电离的光电子角分布（图 1b）。通过 QTMC 理论的计算结果与实验结果非常符合。为了进一步证实理论结果，他们还通过精确求解含时薛定谔方程 (Time-Dependent Schrödinger Equation-TDSE) 对该理论计算给予验证。通过该理论可以直接采用量子轨迹的方法，研究电子在激光场和原子库仑场作用下的干涉动力学，可以建立多光子电离的经典－量子对应关系，从而对强激光场中原子分子电离过程的电子全息、分子结构成像及超快光场量子调控等方面具有重要应用。该研究结果发表《物理评论快报》上【“Classical-Quantum Correspondence for Above-Threshold Ionization” [M. Li et al.,Phys. Rev. Lett 112, 113002 (2014)].】.

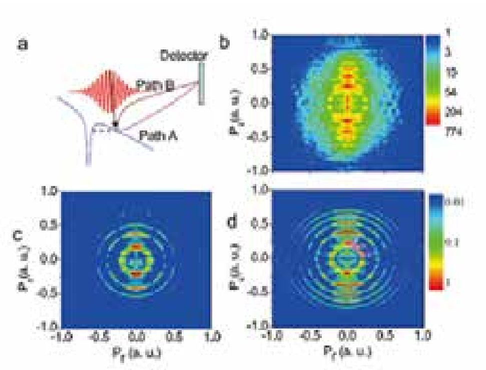


图 1：量子轨迹蒙特卡罗模型基本思想 (a) 及计算结果（c）和 (d)，(b) 为实验测量 Xe 原子的光电子角分布图量

Fig. 1 (a) Illustration of the QTMC model. The subsequent electron motion in the combined laser field and Coulomb potential after the tunnel exit is governed by the Newtonian equations. Electrons could follow the different paths, i.e., path A and path B, and have the same final momenta on detector and will interfere with each other. (b) The experimental PAD of Xe at the intensity of 0.75×10^{14} W/cm^2 (795 nm). (c) The simulated PAD of Xe at the intensity of 0.5×10^{14} W/cm^2 (795 nm). (d) The simulated PAD of Xe at the intensity of 0.75×10^{14} W/cm^2 (795 nm).

I. Quantum-trajectory Monte Carlo (QTMC) theory

The multiphoton ionization and tunneling ionization are the frontier of strong-field physics, which have the broad applications for molecular structural imaging and quantum control. Usually, one can solve the time-dependent Schrodinger equations to understand the ionization of atoms and molecules in strong laser fields. However, this ab initio calculation is not physical transparent. In the collaborative groups of Prof. Yunquan Liu, Prof. Liang-You Peng and Prof. Qihuang Gong, they have developed an intuitive quantum-trajectory Monte Carlo (QTMC) model encoded with Feynman's path-integral approach, in which the Coulomb effect on electron trajectories and interference patterns are fully considered. Experimentally, they have measured photoelectron angular distributions (PADs) with high resolution for multiphoton ionization of xenon atoms in infrared laser fields, which exhibits distinct ATI spots and rings. They achieved an excellent agreement of QTMC calculation with the measured PADs of atoms in multiphoton regime. The QTMC theory sheds light on the role of ionic potential on PADs along the longitudinal and transverse direction with respect to the laser polarization, allowing us to unravel the classical origin of photoelectrons at the tunnel exit. The classical-quantum correspondence and build a bridge between the above threshold ionization and the tunneling theory was studied. This work was published on "Classical-Quantum Correspondence for Above-Threshold Ionization" [M. Li et al., Phys. Rev. Lett 112, 113002 (2014)].

二、强激光场中低于电离阈值的谐波辐射机理

强飞秒激光脉冲作用下原子分子的高次谐波以及阿秒脉冲产生近二十年来一直受到了广泛关注。当谐波辐射的光子能量大于电离阈值时，不考虑原子分子库仑势影响的理论（例如强场近似理论）能够较好的描述谐波产生过程。而对于低于电离阈值的谐波辐射，库仑势将对谐波的产率具有较大的调制作用。目前还没有一个很好的解析理论来进行分析，研究群体采用精确求解含时薛定谔方程的方法详细研究了不同激光参数下谐波产率随着激光参数的变化。

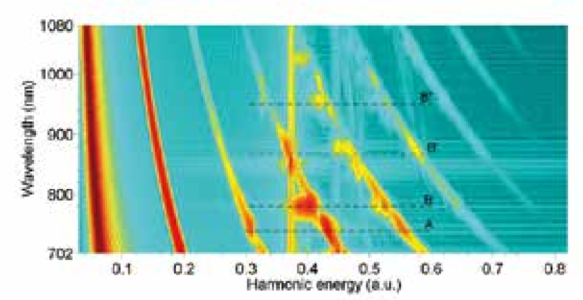


图 2：氢原子不同激光波长下的谐波辐射信号，激光强度为 6×1012 W/cm2。从图中可以看出随着波长变化，谐波产率受到很大的调制，出现很多共振峰和原子线跃迁辐射。

Fig. 2 Harmonic spectra of hydrogen interacting with an intense driving laser at a peak intensity I0=6×1012 W/cm2, with the laser wavelength changed from 702 to 1080 nm. One can see many resonant structures and atomic line emissions.

图 2 展示了通过数值求解含时薛定谔方程所得到的不同激光波长下的谐波辐射信号。从图中可以看出随着波长变化，谐波产率受到显著调制，出现了一些有趣的共振峰和干涉峰结构。利用半经典的理论和推广后的强场近似理论对这种产率调制进行详尽分析，能够清晰解释各个峰产生的位置和不同机理。一方面，发现在低于电离阈值区域内依然存在类似于高于电离阈值时谐波的长短轨道干涉。另一方面，研究表明库伦势的影响主要体现为库伦场中各个激发态作为中间态参与了谐波辐射的过程。这一影响既有可能出现在电离过程中，表现为共振增强。也有可能出现在辐射过程中，表现为对辐射光子能量的调控。这一理论工作将对 VUV 和 EUV 频段的光频梳以及相干光源的实验研究提供重要指导。该研究结果发表《物理评论快报》上【Phys. Rev. Lett. 112, 233001 (2014)】。

II. Mechanisms of below threshold harmonic generation

The harmonic generation when atoms or molecules interact with strong laser field has been paid lots of attention during the last decades due to its application as coherent XUV and attosecond light sources. When the photon energy emitted is large enough, theories without consideration of the Coulomb potential such as strong field approximation can describe this process. But for the low energy photons, Coulomb potential have critical impact on the harmonic yield and analytical theory does not exist in this range. They numerically solve the time-dependent Schrödinger equation of an atom to investigate the mechanisms in the low energy range by varying the laser wavelength and peak intensity. The harmonic spectrum with different laser wavelengths is shown in Fig.2. The harmonic yield is modulated by the laser wavelength. Their analysis through a semi-classical model and the generalized quantum path analysis explained these structures. On the one hand, they confirmed the quantum path interference in this energy range. On the other hand, they identified the influence of Coulomb potential when bound states act as intermediate state during the harmonic generation process. Their theory can help to understand the experimental result of the frequency comb and coherent light sources in EUV range. This research was published in Phys. Rev. Lett. 112, 233001 (2014).

三、纳米光子学器件

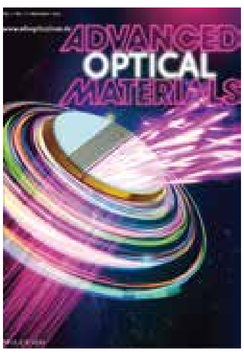
纳米光子学器件在超高速信息处理和光互连等领域具有非常重要的应用前景。金属 / 介电微结构

具有独特的亚波长尺度光场局域和场增强效应，是构造和实现纳米光子学器件的重要平台。

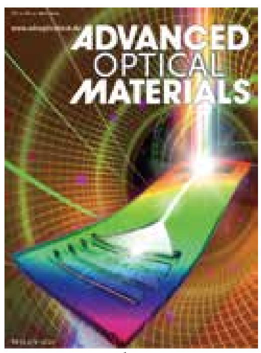
北京大学人工微结构和介观物理国家重点实验室、物理系胡小永教授和龚旗煌院士等提出一种利用表面等离激元带隙工程来实现超宽带定向表面等离激元发射器的新方法，在一维表面等离激元晶体中通过改变晶格周期来调控光子禁带边缘对应的频率，在可见 - 近红外的较宽的范围内实现了超宽带的、单向表面等离激元发射，整个器件尺寸小于 4 μm，工作带宽高达 290 nm，平均消光比高达 30 dB，相关工作发表在重要期刊 Advanced Optical Materials 上（Advanced Optical Materials 1, 792 (2013)），并被选为同期的封面文章，AOM 同期的评述指出“不但为将来的光计算技术提供了极好的、芯片上的光源，而且为构造新型的纳米光子处理器铺平了道路”。

他们还提出了一种通过单个复合微腔相邻共振模式相干耦合实现平面内芯片上可集成表面等离激元感应透明新方法，将微腔特征尺寸减小了一个数量级，仅为 600 nm。利用单个复合微腔所支持的辐射模式与非辐射模式的相干耦合，直接在集成光子回路中实现了平面内片上集成的表面等离激元感应透明，相关工作发表在重要期刊 Advanced Optical Materials 上（Advanced Optical Materials 2, 320 (2014)），并被选为同期的封面文章，工作还被 WILEY-VCH 出版集团科技网站 Materials Views China 专题评述为“不仅有助于推动表面等离激元感应透明的微纳集成光子器件的研究，而且为实现基于表面等离激元回路的超高速信息处理芯片提供了一种新的可能”。在此基础之上，他们利用三个金纳米棱镜对作为 meta 分子，在厚度仅为 40nm 的超薄 meta-surface 中，实现了超强的慢光效应，群折射率达到 4000，提高了一个数量级，实现了超快低功率光开关，泵浦光强降低到 4 KW/cm2，阈值光功率降低 6 个数量级，同时保持 25.3 ps 的超快响应，相关工作发表在重要期刊 Advanced Optical Materials 上（Advanced Optical Materials 2, 1141 (2014)），并被选为同期的封面文章，工作还被 WILEY-VCH 出版集团科技网站 Materials Views 专题评述为“使得利用超材料实现量子固态芯片成为可能，还为构造大非线性和超快响应光子材料提供一条途径”。

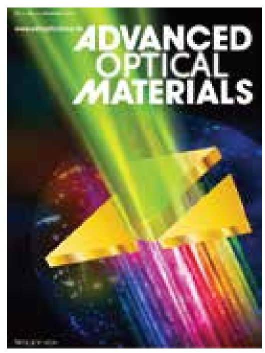
研究工作得到了国家自然科学基金委的“创新研究群体”项目和国家 973 项目等的资助。



a



b



c

图：a) 超宽带 SPP 发射器。b) 片上表面等离激元感应透明。c) 在超薄 metasurface 中实现的超低功率超快光开关

Figures: a) Ultra-broad-band SPP launcher. b) On-chip plasmon-induced transparency. c) Ultralow-power and ultrafast all-optical switching based on ultrathin meta-surface.

III. Nanophotonic devices

Nanophotonic devices play an important role in fields of ultrahigh-speed information processing and optical interconnections. Metal/dielectric microstructures have unique properties of strong light confinement into subwavelength scale, and field enhancement effect, being an important platform for the realization of nanophotonic devices.

Xaioyong Hu and Qihuang Gong proposed a new mechanism to construct ultra-wide band and unidirectional surface plasmon polariton (SPP) launcher based on SPP photonic bandgap engineering. Through modulating the lattice constant of a 1D plasmonic crystal to control the frequency of the stop bandedge, an ultra-wide-band unidirectional SPP launcher was realized. The feature size was only 4 μm. The operating bandwidth reached 290 nm. The average extinction ratio reached 30 dB. This work was published in Adv. Optical Mater.（Advanced Optical Materials 1, 792 (2013)), and selected as the cover article. This work was also evaluated by AOM journal as:” This device provides an excellent optical source on chip for future optical computing technologies and may pave the way to construct novel nanophotonic processor architectures”.

They also proposed a new method to realize in-plane on-chip plasmon-induced transparency based on composite microcavity mode coupling. The feature size of the microcavity was reduced to 600 nm, reduced by one order of magnitude. Based on the interference coupling of superradiant and subradiant modes provided by the composite microcavity, plasmon-induced transparency was realized in plasmonic circuits directly. This work was published in Adv. Optical Mater.（Advanced Optical Materials 2, 320 (2014)), and selected as the cover article. This work was also evaluated by the scientific web Materials Views China of WILEY-VCH publishing company as:” not only help push the study of nanoscale integrated photonic devices based on plasmon-induced transparency, but also provides a new possibility for the realization of ultrahigh-speed information processing chip based on plasmon-induced transparency”. They also realized strong slow light effect in an ultrathin meta-surface having a thickness of 40 nm, using three gold nano-prisms as the meta-molecule. The group index reached 4000, which is enlarged by one order of magnitude compared with previous reports. An ultrafast and low-power optical switching was also realized with a pump intensity of 4 KW/cm2 which is reduced by six order of magnitude, and a ultrafast response of 25.3 ps. This work was published in Adv. Optical Mater.（Advanced Optical Materials 2, 1141 (2014)), and selected as the cover article. This work was also evaluated by the scientific web Materials Views of WILEY-VCH publishing company as:” This allows the realization of quantum solid chips based on metamaterials, and also a strategy for constructing photonic materials with large nonlinearity and ultrafast response”.

These series of works was supported by the Creative Research Group project of the National Natural Science Foundation of China, and the National Basic Research Program of China.

四、单个纳米尺度颗粒的光学检测新原理研究

纳米尺度颗粒的快速检测在环境监测、恶性肿瘤早期筛查和国家安全方面具有十分重要的意义。基于微纳光学的传感技术拥有无标记和抗电磁干扰等优势，为上述应用提供了新的机遇，但在快速探测和超高灵敏度方面仍面临挑战。为此，急需提出新的光学传感原理，突破传统检测极限，获得分辨单个纳米级颗粒的检测能力。

北京大学物理学院肖云峰研究员和龚旗煌教授

领导的研究小组提出了微腔拉曼激光、微腔线宽测量、纳米光纤阵列等传感新技术的原创性思想，既可显著降低实验难度又具有良好的抗噪声能力。实验上，他们制备出高质量的回音壁模式光学微腔和尺寸均匀的纳米光纤阵列，均实现了单个纳米尺度颗粒的快速检测，为下一步实际应用奠定了坚实基础。其中，微腔拉曼激光检测单颗粒的尺寸极限达到 20 纳米，处于国际领先水平。

这些新的原理和技术将推进光学传感的检测极限达到单分子水平，并具有实时便捷等优势。上述研究成果分别发表在《美国科学院院刊》和《先进材料》（封面文章）上。工作得到国际学术界的重视，被 Phys.org 和 Materials Views 等多家国际科技媒体专题图文报道，并引起了大众媒体的关注。相关成果还入选“2014 年度高校十大科技进展”之“单个纳米颗粒光学检测新原理研究”。

浙江大学童利民教授研究组参与了相关研究。

系列研究工作得到了科技部 973 计划、国家自然科学基金委重点项目、人工微结构和介观物理国家重点实验室及量子物质科学协同创新中心的支持。

图：基于光学微腔及纳米光纤阵列的传感示意图及封面。

Figure：Highly sensitive sensors based on optical microcavities and nanofiber arrays.

IV. Single nanoparticle detection by using micro/nano-photonics devices

Optical sensing of nanoscale objects with ultrahigh sensitivity is highly desirable for applications in various fields, such as in early-stage diagnosis of human diseases and in environmental monitoring, as well as in homeland security. Optical sensors based on micro/nano devices are immune to electromagnetic interference and suitable for label free detection, which provides new opportunities for the applications mentioned above, but still face challenges such as in rapid response and ultrasensitive detection. Thus, new mechanisms are urgently required for taking detection to the limit, i.e., for realizing the single nanoparticle resolution.

To this end, a group led by Prof. Yun-Feng Xiao and Prof. Qihuang Gong from School of Physics at Peking University has developed several novel optical sensing mechanisms or designs, such as microcavity Raman laser, resonance broadening measurement and nanofiber array. In experiment, they have successfully fabricated on-chip optical microcavities supporting high-Q whispering gallery modes (WGMs) and nanofiber array with a uniform diameter. By using these optical devices and the detection mechanisms, they have realized rapid detection of single nanoparticles experimentally. For instance, the detection limit of single nanoparticles by microcavity

Raman laser reaches the record size - 20 nm in radius. These new methods and techniques hold potential for taking the optical detection limit to the single molecule level, and realize the real-time detection. The results were published in Proceedings of National Academy of Sciences and Advanced Materials (selected as cover articles), and were highlighted by Phys.org and Materials View. Relevant progress was also selected as Top-10 Progress in 2014 by MOE.

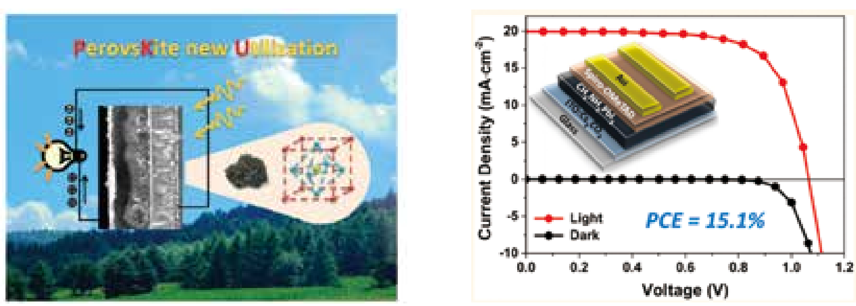
Professor Limin Tong's group from Zhejiang University also has contribution to the work.

五、钙钛矿太阳能电池

太阳能的利用是当前物理、能源、材料等领域交叉研究的前沿热点。近两年来，基于钙钛矿型有机 - 无机杂化材料的新型太阳能电池在学术界和产业界吸引了广泛的关注，其光电转换效率已迅速攀升到 20% 以上（经权威机构验证），并有希望达到晶体硅电池的 25% 的水平。相对于其他类型的太阳能电池，这类电池还具有成本低、吸收光谱宽、吸收系数高、制作工艺简单的优势。

北京大学人工微结构和介观物理国家重点实验室成员肖立新教授、朱瑞研究员和龚旗煌院士等人的研究团队在已有工作的基础上，积极开展相关前沿研究，取得了系列重要进展。首先，在形貌控制方面，肖立新教授和龚旗煌院士等人通过分步溶液成膜方法对掺氯钙钛矿材料进行优化，相对于一步溶液成膜方法，微观形貌容易控制，器件效率得到极大提高，并进一步研究钙钛矿薄膜材料的成膜条件，实现对钙钛矿薄膜形貌的调控，成功制备了介观结构的钙钛矿太阳能电池，同时提高了太阳能电池的吸光能力及电荷传输能力，研究结果分别发表在 Chem. Commun. 2014, 50, 12458 的内封面文章及 Nanoscale, 2014, 6, 8171 上。同时，针对钙钛矿电池急需解决的稳定性问题，肖立新教授和龚旗煌院士等人开发了一种新型疏水性空穴传输材料使器件的稳定性得到极大改善（Chem. Commun. 2014, 50, 11196），相关工作已经申请中国发明专利。

“青年千人”研究员朱瑞博士和龚旗煌院士针对钙钛矿太阳能电池中的界面工程问题，利用碱金属盐修饰透明导电电极表面，优化了透明电极与钙钛矿活性层材料之间的能级匹配，实现了不依赖于氧化物致密层的钙钛矿型太阳能电池结构，该器件的光电转换效率可达到 15.1%。结果表明，



图：a) 钙钛矿太阳能电池的形貌控制研究。b) 钙钛矿太阳能电池的界面工程研究。

Fig. (a) Morphology control for perovskite solar cells; (b) Interface engineering for perovskite solar cells.

通过界面修饰工程可以替代常规的致密氧化物薄膜，实现电子的有效收集，这将有助于简化器件的制备工艺，同时也使钙钛矿太阳能电池仍保持良好的器件性能。该工作即将发表在 ACS Nano（ACS Nano, 2014, 8, 10161）上，是该杂志当月访问量最多的文章之一。相关成果也已经申请中国发明专利。此外，该团队还结合形貌控制的方法，实现了效率超过 18% 的钙钛矿太阳能电池器件，相关结果正在整理投稿中。

该研究工作得到国家自然科学基金委、科技部、北京大学、介观物理国家重点实验室和 2011 协同创新项目的支持。

V. Perovskite Solar Cells

Solar energy utilization is the frontier of multidisciplinary fields, including physics, energy, and material science et.al. During the past two years, photovoltaic technology based on organic-inorganic hybrid perovskite material has attracted extensive attention in academia and industry. The light-to-power conversion efficiency has been boosted to over 20% (verified by NERL). The expected efficiency in near future will be 25%, which is similar to that for monocrystalline silicon cell. Compare to other type of solar cells, these mesoscopic structural perovskite solar cells possesses many advantages, such as the low fabrication cost, broad spectral absorption, high absorption coefficient, and simplicity in processing.

Prof. Lixin Xiao, Prof. Rui Zhu, and CAS Academician Prof. Qihuang Gong have carried out intensive studies on perovskite solar cells and achieved significant progresses. For example, Prof. Lixin Xiao, and Prof. Qihuang Gong adopted dual-step processing to optimize perovskite film device containing chloride. Comparing to mono-step method, it is easier to control micro morphology of the perovskite active layer. Further optimization of the device fabrication has been performed. Enhancement of the light absorbing and charge transferring in the devices has been achieved, resulting in perovskite solar cells with improved efficiency. The studies were published in Chem. Commun. (2014, 50, 12458) as inner page cover story and Nanoscale (2014, 6, 8171). Stability is also a key issue for the perovskite solar cells. The team has developed and patented a new hydrophobic hole transporting material which can greatly improve the cell’s stability. (Chem. Commun. 2014, 50, 11196)

The research group led by Prof. Rui Zhu and Prof. Qihuang Qong has also achieved progresses in the interface engineering of perovskite solar cells. Alkali salt solution was used to modify the ITO substrate surface to achieve the optimized interface energy level alignment, resulting in efficient electron-selective contact. Devices based on the modified ITO surface could achieve a power conversion efficiency exceeding 15%, together with improved device stability under specific conditions. These results imply that interface engineering provides a promising approach to simplify device fabrication for perovskite solar cells. This work has been published on ACS Nano (ACS Nano, 2014, 8, 10161). This paper has been of the “most-accessed” articles during the month of publication. The patent application has been also submitted. Moreover, with the effort of morphology, the group has achieved a higher efficiency over 18%. The manuscript based on this result is under preparation.

The works are supported by NFSC, MOST, Peking University, State Key laboratory For Artificial Microstructure and Mesoscopic Physics, and 2011 Project.

04 重离子物理研究所 Institutes of Heavy Ion Physics

研究领域涉及先进粒子加速器物理与技术、基于加速器的核技术及应用以及医学物理等，拥有 4.5MV 单级静电加速器、26 串列静电加速器、^{14}C 测量加速器质谱计、射频超导加速器、加速器中子照相系统等大型仪器设备，最近又建成了基于 200 太瓦激光器的激光等离子体加速器实验室。 研究所现有教职工 45 人，其中中科院院士 1 人，教授 8 人，副教授（含高级工程师）21 人，讲师 2 人，工程师 10 人，近年来引进多名优秀青年学者。

Research fields of the institute include physics and technology of advanced particle accelerator, nuclear technology and applications based on accelerators, nuclear and medical physics. There are many large research equipments in the institute, such as 4.5MV Van de Graaff accelerator, 26MV tandem accelerator, ^{14}C compact AMS, superconducting RF electron accelerator and RFQ accelerator-based neutron radiography system. A laser-plasma accelerator laboratory based on a 200 TW laser system has just been built. There are 45 faculty members in the institute, consisting of 1 CAS academician of CAS, 8 professors, 20 associate professors, 2 assistant professors and 10 engineers. Several outstanding young researchers have been introduced in recent years.

一、超导光阴极注入器 2K 载束稳定运行

光阴极注入器作为电子源被广泛用于直线加速器，而射频超导光阴极注入器则是目前国际上产生高平均流强、低发射度和短脉冲电子束的一个重要方向。北京大学射频超导研究团队于 2001 年提出了一种结合皮尔斯电极和超导加速腔的紧凑型 DC-SRF 注入器结构，被国际上认为是三种有潜力的射频超导注入器结构之一，其可行性已被早期的 1.5-cell 原型注入器所证实。最近，射频超导课题组研制了一台 3.5-cell 超导光阴极注入器以及 2K 低温系统、驱动激光器、光阴极制备室、全固态微波功率源以及低电平控制系统等辅助设备。

作为中国第一台用于超导直线加速器的 2K 氦循环低温系统，北京大学的大型 2K 低温经仔细调试后达到了稳定运行状态，氦气压稳定度好于 ±0.1 mbar，2K 低温下制冷能力达到 65W，超过了 57.5W 的设计指标。为改进驱动激光的稳定性，我们重新设计了激光倍频系统，采用双 BBO 晶体补偿走离效应，获得了大于 2W 的紫外激光功率且稳定度好于 5%。通过改善光阴极制备室的真空度和制备流程，Cs2Te 光阴极的量子效率到达了 3.5% 且能持续 10 天以上。为稳定 3.5-cell 超导腔内的电磁场，我们发展了数字化幅相控制系统，其幅度稳定度可控制在 0.1% 以内，相位稳定度在 0.1 度以内，而且既能在连续波状态下工作，也能在宏脉冲状态下工作。新建的束流实验线包含螺线管透镜、四级透镜、二级偏转磁铁、YAG 屏和发射度仪等束流传输和诊断元件（图 2）。

经过系统实验研究，DC-SRF 光阴极注入器于 2014 年实现了稳定出束，电子束能量为 3MeV, 占空比为 7%，宏脉冲内平均流强为 0.55mA, 束流发射度约为 3.0 mm.mrad。该电子束已经被用于产生高重频 THz 的实验研究（图 3）并将用于超快电子衍射等其它应用。 DC-SRFDC-SRF 光阴极注入器稳定出束是我国首次实现 1.3GHz 超导加速结构在 2K 低温下载束稳定运行，相关工作在第 16 届国际射频超导会议上做大会邀请报告。

I. Stable operation of DC-SRF photo- injector at 2K low temperature

Photocathode injectors are widely used for linac accelerators as electron sources to generate high-density, high brightness electron bunches. Superconducting Radio-Frequency (SRF) injectors are expected to provide electron beam with high average beam current, low emittance and short pulse. DC-SRF injector, which combines a DC pierce gun and a superconducting cavity, was first proposed by Peking University in 2001. It is a potential candidate of SRF injector and the feasibility was demonstrated with a 1.5 cell cavity prototype. Recently an upgraded DC-SRF injector with a 3.5-cell superconducting cavity has been designed and constructed. For stable operation of the DC-SRF injector, auxiliary facilities including 2K helium cryogenic system, drive laser, photocathode preparation chamber, solid RF amplifier, LLRF control system etc. are also developed or improved.

As the first closed-loop 2K cryogenic system for superconducting accelerator in China, the performance of the 2K cryogenic system for DC-SRF injector is satisfactory after careful commissioning. The stability of the helium pressure is better than ±0.1 mbar, and total refrigeration capacity at 2 K is more than 65 W, which is larger than the designed value of 57.5W.

To improve the stability of drive laser, we have constructed new second harmonic generator (SHG) and forth harmonic generator (FHG). To compensate the walk-off effect, two BBO that being aligned with their respective optical axes in alternating direction was adopted. The maximum UV power of 2W with stability better than 5% has been reached. The vacuum in the Photocathode preparation chamber was improved by using NEG pump and a process for better preparation which deposit more cesium on sample surface has been adopted. The quantum efficiency of Cs2Te photocathode is higher than 3.5% and can be kept for more than 10 days. In order to stabilize the accelerating field in 3.5-Cell cavity, a digital Low Level Radio Frequency (LLRF) control system was developed. Field stability is better than 0.1% for amplitude and 0.1deg for phase. A new beam line has been designed and constructed for beam transport and diagnostics. Solenoid lenses, quadrupole magnets and dipole magnets are used for beam focusing and deflecting. There are many beam diagnostic devices such as YAG or quartz screens, faraday cups and a beam emmittance meter in the new beam line (See Fig.2).

Fig.1 DC-SRF injector with beam line and 2K cold box

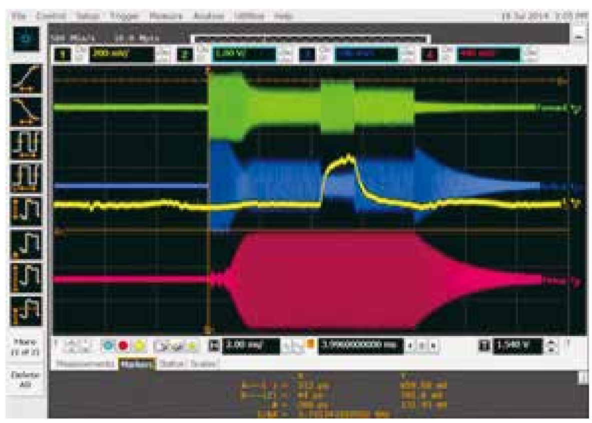


Fig.2 THz radiation signal (yellow line) and RF signals

After systematic experiments, a stable beam current has been obtained for long-term operation. The electron beam energy is higher than 3MeV, duty factor is 7%, the average beam current is 0.55mA in macro pulse and the beam emmittance is about 3.0mm.mrad. The electron beam has been used for the preliminary experiment to generate THz radiation and will be used for other applications such as ultrafast electron diffraction. It is the first time for the stable operation of SRF linac with 1.3GHz cavity at 2K low temperature in China. This work was reported as an invited talk in 16^{th} SRF conference.

二、核能及相关材料的离子辐照损伤机理研究

核能系统中的材料问题，特别是材料的抗辐照损伤性能，不仅决定了核能系统的燃烧效率、输出功率以及使用寿命，同时也是核能系统安全性的重要保障。运用载能离子束不仅可以快速模拟反应堆中子的辐照损伤效果，而且可以通过可控的辐照条件细致地研究材料辐照损伤的机理。

1.MAX 相金属陶瓷的辐照损伤机理研究

金属陶瓷材料（MAX）具有优异的性质，是近年来获得广泛关注的核能系统应用材料之一。通过大量实验研究，我们确认了部分 MAX 相材料在经过高达上百 dpa 的离子辐照后，其结构依然能够保持比较完整，没有完全非晶化，这个结果表明它们具有非常好的抗辐照能力。通过系统实验与计算机模拟，我们确认上述材料的辐照稳定性来源于 A 层的特殊性，主要是该层所导致的缺陷恢复通道以及稳定的替位缺陷。通过我们以及合作单位的工作，MAX 材料被列入国家下一代核燃料包壳材料探索计划的两种候选材料之一。相关研究成果在 ACTA Mater., J. Am. Ceram. Soc., JAP., JNM., NIM B 等期刊发表，并在第十七届绝缘体辐照效应及第十八届离子束材料表面改性国际会议上做大会特邀报告。

2.ZrO2、ODS 钢及 SiC 等材料辐照损伤机理研究

系统研究了单晶、多晶及纳米晶 ZrO2 及 ZrO2/W 纳米多层膜的离子辐照损伤，实验发现单晶 ZrO2 的多种缺陷演化行为及与能损的关联、ZrO2 晶界和多层膜界面对缺陷及氦泡演化的影响及何种纳米多孔结构有助于氦泡的输运。利用双束和三束离子辐照 ODS 钢及 SiC，研究了 H、He 与移位损伤的协同作用及对材料肿胀等的影响。实验及理论研究了载能离子与 SiC 及 SiC 纳米线的相互作用，结果表明由于纳米线的有限体积以及高表面 - 体积比，纳米线的溅射产额和非晶化程度等辐照损伤特性表现出与体材料不同的特点。相关研究成果在 J. Am. Ceram. Soc., JNM., NIM B 等期刊发表，并有三名博士生分别在国际学术大会上获最佳海报奖。

3. 载能离子与 2D 材料相互作用模型建立

离子与 2D 材料相互作用的特殊规律一直是获得广泛关注但没有解决的问题，并成为制约离子束技术在其中应用的瓶颈。我们通过系统的实验和理论研究，确认了传统的辐照损伤模型不能用来描述离子与 2D 材料相互作用过程，入射离子的电荷状态以及化学性质对离子能量损失具有明显的影响，特别是在低能区域，上述因素占主导地位。同时，我们利用分子动力学方法，对上述过程的物理机制进行了详细描述，并与实验结果定量符合。上述发现揭示了 2D 材料与传统材料与离子相互作用过程之间的差异，为今后离子辐照技术在 2D 材料中的应用奠定了基础。相关工作发表在 Phys. Rev.B、J. Chem. Phys.、JAP、Chem Comm、J. Phys. Chem. C、Chem. Phys. Lett.、J. MATER. CHEM. 等学术期刊上。

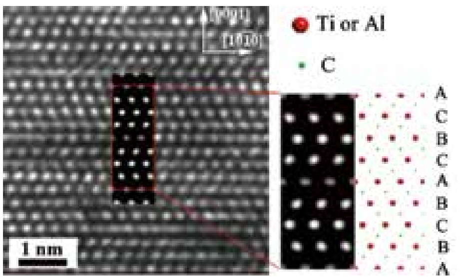


FIG. 1 HRTEM image of Ti_3AlC_2 irradiated at 5×10^{16} cm^2; the simulated phase contrast, shown in the inset, is superimposed on the experimental image.

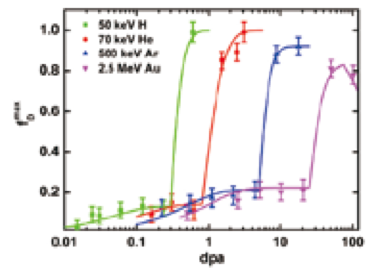


FIG.2 The evolutions of maximum fraction of displaced atoms in Zr sublattice as a function of irradiation dose (in dpa) for YSZ samples irradiated with various ions.

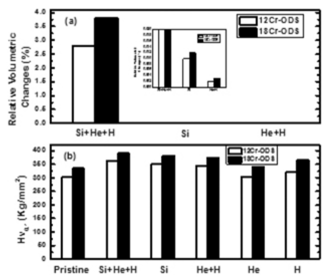


FIG. 3 The swelling and Vickers hardness value of pristine and irradiated12,18Cr-ODS steels

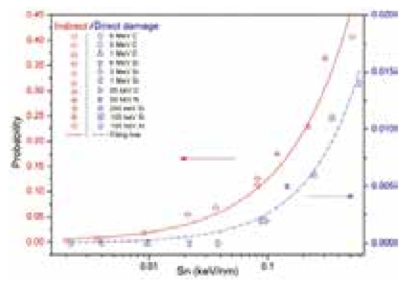


FIG. 4 MD simulations, and are plotted with respect to Sn in graphene and S_n in SiO_2.

II.

Damage mechanism of MAX phase metal ceramics

The structural transitions of several MAX phase were investigated over a wide ion fluence range. No amorphization occurs even at the ion dose larger than 150 dpa for Ti3AlC2, indicating a great tolerance to irradiation-induced amorphization. Due to the similar structural transition process with some complex oxides, it is assumed that the great irradiation tolerance of MAX phase results from the low formation energy of antisite defects. Based on first-principle calculations, the radiation tolerance of two M3AX2 and four M2AX phases were studied, covering all the Mn+1AXn phases previously investigated with experiments. Based on our research, MAX phase has been selected as one of the candidate in national ATF fuels R&D plan.

Damage mechanism of ZrO_2, ODS steels and SiC irradiated by energetic ions

Irradiation damage mechanism of single-, poly- and nano-crystaline ZrO2 and ZrO2/W nano-multilayer were investigated experimentally. Defects evalution and energy-loss dependence for crystaline was observed and the influence of grain boundary and interface on the evalution of defects and He bubbles was investigated. Our results also showed that nanocrystalline zirconia film with interconnected nanoporous structure reveals good tolerance for irradiation of high-fluence He. Under the multi-ion-beam irradiation, the 12, 18Cr-ODS steels demonstrated a largest swelling and hardening trend, which is caused by the synergistic effects of heavy ions, helium and hydrogen. Compared with bulk material, the sputtering yield of the SiC NW is much higher, and the sputtering yields show a different dependence to the nuclear stopping power because the NW's limited volume stops the collision cascade from fully evolving.

Interaction of energetic ions with 2-dimentional materials

Because of the special structure of 2D materials, the interaction process between these atomic-thin materials and energetic ions is quite differents. We found that, both with experiments and with computer simulations, the energy loss of the incident ions depends on the ion charge and its chemical-bond with the target atom, especially in low energy region from several eV to hundreds eV. We also confirmed that, the irradiation damage to the graphene supported with a substrate is determined by the substrate but not the graphene itself. In other words, most of the damage in graphene is attributed to the sputtered atoms from the substrate. Our results reveal the new mechanism for ion-2D materials interaction, and this will be very helpful for applications of ions in engineering 2D materials such as graphene etc.

三、EAST 和 HL-2A 托卡马克装置上先进聚变中子发射能谱诊断研究

中子发射是聚变反应过程发生的主要标记和对于人类聚变能源研究进展快慢的直接度量。中子诊断对于聚变装置的输出功率评估和燃烧等离子体物理研究具有独特的重要作用，也是未来 DEMO 聚变堆的最重要的产物诊断手段之一。根据 ITER 装置中子诊断技术发展和国际上第一个全超导非圆截面托卡马克装置 E A S T 高参数运行条件下燃料快离子物理研究的需求，北京大学中子与聚变等离子体研究团队开展了基于紧凑型数字化高探测效率中子谱仪和高能量分辨飞行时间中子谱仪诊断高温等离子体的研究工作。

针对未来大型聚变装置诊断空间的限制并满足中小型磁约束聚变装置上低强度中子场的能谱诊断需要，我们系统地发展了基于液体闪烁体探测器、芪晶体和 scCVD 金刚石探测器的紧凑型全数字化中子谱仪。在这些谱仪上首次提出和实现了基于矩分析和时域延迟线成形算法的两种数字化脉冲形状甄别技术，而一种简洁地确定各向异性光输出函数的技术使得芪晶体中子谱仪的快速准确刻度成为现实。在 HL-2A 装置上首次由中子谱仪诊断实现了中性束加热效果评估和聚变等离子体的锯齿不稳定性研究。通过对 EAST 上低杂波和离子回旋波加热的等离子体诊断， 在国际上首次将中子谱仪直接诊断托卡马克等离子体离子温度的极限成功下推到 1keV 以下。

在 2014 年 6 月 22 日，国际上第一个双环式球形阵列聚变中子飞行时间谱仪 TOFED（Time Of Flight Enhanced Diagnostics，飞行时间强化型诊断）在 EAST 托卡马克上建成。该 TOFED 谱仪（见图 1）将独特的双环式球形的探测器阵列结构（见图 2）和基于高速全数字化数据采集系统的双环动态能选技术相结合，使得在快离子相关中子能区的测量信噪比在国际最先进的 TORFOR 谱仪（建在 JET 托卡马克装置上）基础上提高了一个数量级。TOFED 系统测量 DD 聚变中子能谱的能量分辨率可达 6.6%。在高计数率条件下工作时，谱仪的全数字化数据采集系统的数字化分辨率小于 1.5%，时间分辨小于 1ns。作为国际上第一个长脉冲托卡马克上的先进聚变中子谱仪，TOFED 系统已经为未来聚变堆实验的燃料离子温度诊断、离子成分分析和燃烧等离子物理研究打下了坚实的基础。

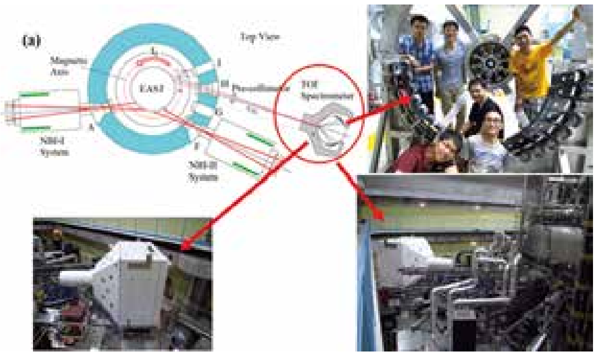


Fig. 1 The TOFED spectrometer installed in the EAST torus hall.

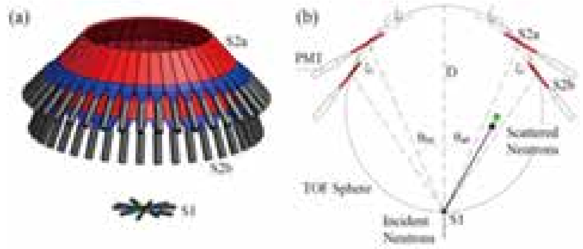


Fig. 2 3D representation of the TOFED spectrometer (a) and a vertical plane drawing (b) showing the positions of detectors on the sphere of diameter D. Each S2 ring consists of 40 detector units of scintillators and PM tubes with S1 being a five layered detector assembly.

III. Advanced neutron emission spectroscopy diagnostics for EAST and HL-2A fusion experiments

Neutron emission in a fusion device indicates how closely the fusion plasmas approach the ultimate goal of a self-sustained fusion power plant. The plasma neutron diagnostics are of increasing importance for characterization of the fusion burning process and for determination of the performance of future fusion devices such as ITER and DEMO. In recent years, the fusion neutron and plasma physics team at Peking University has been deeply involved in the advanced neutron emission spectroscopy (NES) instrumentation and the fusion plasma NES diagnosis at the EAST and HL-2A tokamak devices, and also resulted in more than 20 publications in international prestigious scientific journals.

The compact neutron spectrometers, based on liquid scintillators, a stilbene crystal and a scCVD diamond detector with 5 μm of LiF layer, have been investigated and employed for the plasma discharges with the low neutron emission intensities from the small and midsize magnetic confinement devices. Two digital pulse shape discrimination techniques, including the moment analysis (MA) and digital delay-line-shape (DDLS) method, were first presented and achieved good neutron/gamma discrimination performances in these compact systems. A quick and simple method for the determination of anisotropic light output makes it easy to characterize the stilbene crystal neutron spectrometer accurately. The evaluation of the heating effect in HL-2A neutral beam injection experiments and the diagnosis for plasma sawtooth instability were first performed by NES. Plasma ion temperature values, which are less than 1 keV, were deduced from the measured neutron spectra in EAST dd discharges with lower hybrid wave injection and ion cyclotron resonance heating for the first time.

The advanced neutron spectrometer time-of-flight enhanced diagnostics (TOFED) (Fig. 1) has been developed and installed at EAST in June 22, 2014 and will be used to study the behavior of fast ions produced by the injection of external auxiliary power. The new design (Fig. 2), where the second scintillator is split into two spherical zones, is shown to enhance the discrimination capability compared to the TOFOR at JET tokamak and will provide fusion neutron spectra with reduced admixture of multiple scattering events which is essential for increasing the sensitivity to weak components in the neutron emission. The energy resolution of the TOFED spectrometer is

6.6%. A new fully digital data acquisition system can provide a digitizing resolution better than 1.5% and a time resolution <1 ns, compatible with high count rate event recording. As the first high-performance neutron spectrometer on a long pulse tokamak, TOFED would be a powerful diagnostic of ion temperature and fuel ion composition and the burning plasma diagnostics in future fusion reactor experiments.

四、临界密度等离子体产生高能准单能电子和高亮度伽玛辐射

利用超强激光与等离子体相互作用产生高能电子，目前最主要的途径是在激光尾波场中实现。然而这种尾波场产生的电子束密度很低，电子数目很少。另一方面，利用电子与激光共振也是一种有效的电子加速机制。然而由于等离子体环境非常复杂，预加速的电子只有很少的一些能够满足共振条件，因此极大限制了共振加速的实际应用。我们在前期的研究中发现，共振加速在圆极化激光下和线极化激光下有很大的不同。圆极化激光下，电子的共振加速更加有效，也更加稳定。利用圆极化激光与近临界密度等离子体相互作用，可以同时产生很强的准静态角向和轴向磁场，这被称为逆法拉第效应。该研究小组在前期的工作中对这种自生磁场进行了深入的研究。

最近的研究工作中发现，当准静态轴向磁场足够强的时候，在激光通道中心会俘获高密度的电子束。这些被俘获的电子，由于受到激光的驱动，会不断调整自身的频率和相位，以匹配共振条件。一旦共振条件匹配，这些电子就可以被持续的加速，进而可以产生具有过临界密度，螺旋结构以及平台能谱特性的准直电子束。这些共振电子的加速过程非常类似于最早提出的逆自由电子激光加速机制。审稿人评论认为这个工作非常有趣并且会引起同行的极大兴趣：I found this work to be interesting and potentially of great interest to the community. 这种自匹配共振加速的电子束具有广泛的应用前景，最近我们的实验结果表明，采用碳纳米管可以有效地用于提高离子加速效率和产生高亮度的 MeV 伽玛射线。

该项研究得到国家科技部重大仪器开发专项、国家自然科学杰出青年基金、基金委重点项目、863 项目和某专项基地项目的资助。还得到了核物理与核技术国家重点实验室和北京大学应用物理与技术研究中心资助。

参考文献：

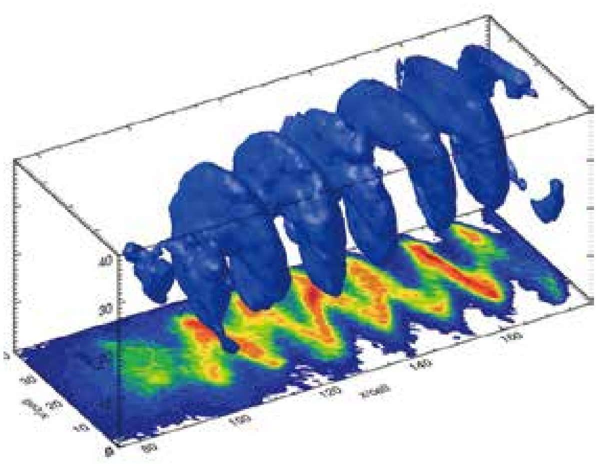


图 1 电子束能量密度三维分布图

Fig.1 Energy distribution of electron beam in 3D space

IV. Quasimonoenergetic electron beam and brilliant gamma-ray radiation generated from near critical density plasma

We show a novel self-matching resonance acceleration regime for generating dense relativistic electron beams by using ultraintense circularly polarized laser pulses in near-critical density plasmas （for example Carbon Nanotube Target）. When the self-generated quasistatic axial magnetic field is strong enough to pinch and trap thermal relativistic electrons, an overdense electron bunch is formed in the center of the laser channel. In the trapping process, the electron betatron frequencies and phases can be adjusted automatically to match the resonance condition. The matched electrons are accelerated continuously and a collimated electron beam with overcritical density, helical structure, and plateau profile energy spectrum is hence generated. Furthermore, it is found that a high current quasi-monoenergetic electron beam and a peaked brilliant gamma-ray beam can be generated by irradiating an ultra-intense laser pulse on uniform near critical density plasma with a proper laser spot radius, a quasi-monoenergetic electron beam with charge of > 10^11 can be generated, while bright gamma-ray photons are emitted in a small polar angle range. It is similar to a conventional wiggler synchrotron, except that the curvature radius of electron orbits in the laboratory coordinate frame measures in microns rather than meters, which had been demonstrated in experiments recently.

This work was supported by National Basic Research Program of China (Grant No.2013CBA01502), National Natural Science Foundation of China (Grant Nos. 11025523, 10935002, 10835003,J1103206, 11205010) and National Grand Instrument Projetc (2012YQ030142).

05 等离子体物理与聚变研究所 Institute of Plasma Physics & Fusion Studies

等离子体物理与聚变研究所于 2008 年 12 月 26 日正式成立，王晓钢教授任所长。目前等离子体物理与聚变研究所共有 6 人，其中中科院院士（双聘）1 人，教授 1 人，长江讲座教授 1 人，“北大百人”1 人，“青年千人”2 人。目前在读博士生 29 名、硕士生 4 名。

等离子体物理与聚变研究所成立以来，主要在磁约束等离子体、空间等离子体方向开展理论分析、大规模数值模拟，以及实验数据分析等研究。最近还在聚变诊断方法方面开展工作。相关研究成果在 Nature Physics 发表论文 3 篇，Physics Review Letters 4 篇；同时还在 Nuclear Fusion、Physics of Plasmas、Journal of Geophysics Research 等国际等离子体物理主要刊物上发表论文 30 余篇。我所先后承担科技部国家磁约束核聚变能发展研究专项、973 项目课题、国家自然科学基金委重点项目、教育部博士点基金等科研项目近 20 项，总研究经费近 4 千万元。2013 年，林志宏教授受聘为项目首席科学家的《托卡马克大规模数值模拟》项目获得国家磁约束核聚变能发展研究专项立项资助；李博研究员获得国家磁约束聚变能发展研究专项的人才项目资助；2014 年，肖池阶研究员承担了国家磁约束聚变能发展研究专项的一个理论课题。

等离子体物理与聚变研究所与相关北大研究单位（北京大学聚变模拟中心、应用物理中心、科维理天文与天体物理研究所、地空学院等）、及国内外聚变与等离子体物理研究人员建立长期有效的合作关系，

近年来等离子体物理与聚变研究所在研究生培养方面成绩斐然，在国内外已有初步影响。林志宏教授指导的张桦森同学 2012 年荣获蔡诗东等离子体物理奖。王晓钢教授指导的博士生席鹏伟、马晨昊、赵登等三位同学则分别被邀请在 2013 年、2014 年的美国物理学会等离子体物理分会年会上做大会邀请报告。

Institute of Plasma Physics and Fusion Studies (IPPFS) at Peking University (PKU) was established in December 2008 with Professor Xiaogang Wang serving as the director. Currently there are 6 faculty members and more than 30 graduate students at IPPFS. The main research topics of IPPFS include magnetic fusion energy, laser plasma interaction, and space plasma physics. Researchers at IPPFS have published more than 30 referred papers in Nature Physics, PRL, Nuclear Fusion, Physics of Plasmas, etc. Plasma physics is one of the major research fields in the State Key Lab for Nuclear Physics and Technology.

IPPFS has also established fruitful collaborations with researchers at other PKU research centers (including Fusion Simulation Center, Center for Applied Physics, KIAA, and School of Earth and Space etc), and with major national and international fusion energy and plasma physics programs.

托卡马克边缘局域模触发机制与湍流的模拟研究

研究托卡马克边缘局域模的触发和控制，以及相关的等离子体湍流输运等，对于未来聚变反应堆的运行有着重要意义。

通过与美国劳伦斯 . 利弗莫尔国家实验室徐学桥博士、美国通用原子能公司 Ronald Waltz 博士等国际一流学者合作，王晓钢教授指导的三位博士生（席鹏伟、马晨昊、赵登）在边缘局域模（ELM）的触发机制，以及等离子体湍流的数值模拟代码开发方面取得了一系列具有国际先进水平的成果。他们分别受邀在美国物理学会等离子体物理分会（APS-DPP）年会上作大会邀请报告。其中席鹏伟同学更是首开先河，成为首位在此会议上作大会邀

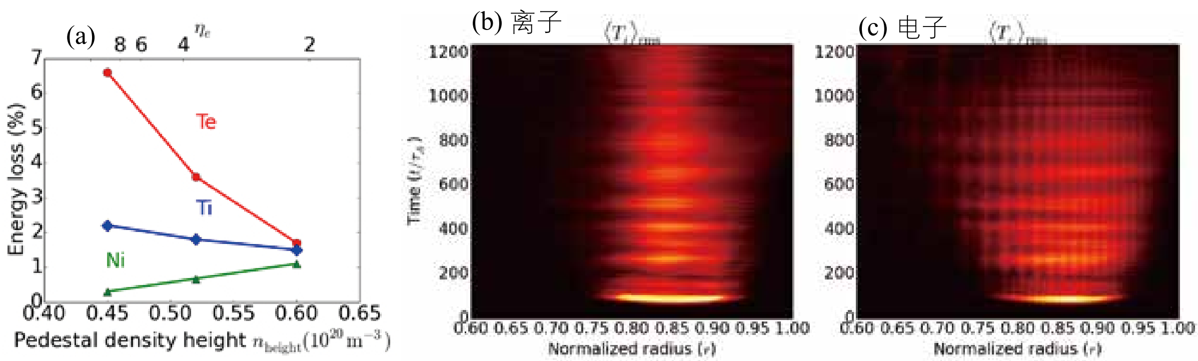


图 1：(a) 随着台阶区密度升高，电子温度提供的能量损失显著降低，与实验相符；(b) 离子湍流的径向宽度随着时间没有变化，没有湍流径向传播效应；(c) 由于湍流径向传播效应，电子湍流的径向宽度随着时间逐渐增加，图中的竖条纹是由电子朗道阻尼效应产生的。

Figure 1: (a) The conductive energy loss from the electron temperature perturbations decreases when the pedestal density increases, which is consistent with experimental results; (b) The radial width of ion turbulence intensity is not changed during the nonlinear evolutions and has no spreading effects; (c) Because of the inward turbulence spreading effects, the radial with of electron turbulence intensity increases during the nonlinear phase; the stronger electron Landau resonance effects generate the vertical stripes in the contour plot.

请报告的中国在读研究生。

一．2010级博士生席鹏伟与徐学桥教授发展了非线性ELM爆发判据。他们通过数值模拟研究发现ELM的爆发过程是完全非线性的，给出了ELM爆发的非线性判据、并证明原来的线性不稳定性判据对应于非线性判据的一种极限情况。该结果证明表明有望通过调节等离子体湍流来控制ELM。这为实验上已有的ELM控制手段提供了新的理论解释。该成果由席鹏伟同学在APS-DPP 2013年会上做了大会邀请报告，并发表在2014年的美国《物理评论快报》上(P.W.Xi, X.Q.Xu, P.H.Diamond, Phys.Rev.Lett, 112, 085001(2014))。

二．2011级博士生马晨昊与徐学桥教授深入研究了ELM爆发后的湍流传播过程，发现在ELM的初次爆发后，由于湍流的径向关联效应，在边缘线性不稳定区域形成的湍流能够在线性稳定区域激发湍流，并导致湍流沿径向向内传播，对总能量损失有重要贡献；由于电子有较强的朗道共振效应，在压强相同而较低的台基密度下，电子温度扰动提供了很大的湍流传播输运和能量损失，而离子温度扰动则没有很强的湍流传播效应（C.H.Ma, et al, Phys. Plasmas, 22, 010702 (2015)）。湍流传播引起的输运在一定程度上解释了实验中对ELM能量损失的定标率。马晨昊在APS-DPP 2014年会的大会邀请报告上介绍了该结果。

三．2011级博士生赵登与R.E. Waltz教授合作，通过开发全回旋动理学代码rCYCLO，动态追踪非线性耦合在低频漂移波中的高频离子回旋运动，找到了回旋平均时被忽略掉的效应。从而证明回旋平均动理学可用于托克马克稳态湍流模拟，并定量给出了该理论的适用范围。赵登在APS-DPP 2014年会的大会邀请报告上报告了该成果。

Numerical simulations on the edge localized modes and plasma turbulences

It is believed that controlled nuclear fusion can eventually solve a major world energy problem -the production of electricity. Tokamaks in high energy confinement regimes (H-mode) are the most promising nuclear fusion plasma devices to reach the goal. However, H-mode plasmas are generally characterized by the occurrence of edge localized modes (ELMs), periodic eruptions of particles and energy, which cause serious erosion on plasma facing components and dramatically reduce confinement in future large tokamak reactors. Thus, it is of crucial importance to understand the mechanism of ELM crashes and energy loss associated with ELMs.

During last two years (2013 and 2014), the Institute of Plasma Physics and Fusion of PKU have a lot of outstanding achievements in the study of ELMs and plasma turbulences by collaborated with Dr Xueqiao Xu and Dr. Ronald E.Waltz, both principal scientists from US Lawrence Livermore National Laboratory, and General Atomics, respectively. Three Ph.D students, Mr Pengwei Xi, Mr Chenhao Ma and Mr. Deng Zhao, were honored to have been separately selected as an invited speaker for two consecutive years in a row in 2013 and 2014 APS-DPP annual meeting, which is a top international academic conference in fusion community. Mr Pengwei Xi is also the first Ph.D student registered at a Chinese university to receive such honor.

1.Mr Pengwei Xi, a 2010 grade PhD student, and Dr. Xu developed a new nonlinear criterion for the onset of ELMs. They study the evolution of ELM crash by nonlinear simulations. They find that before the perturbation can trigger ELMs, there is already wave-wave interaction based on phase evolution, and this limits the growth time of linear instability. Thus, the onset of ELM is a nonlinear process rather than a linear process, which is widely assumed in previous studies. They derived a nonlinear criterion for the onset of ELMs and prove that the linear criterion is just a limit of the nonlinear criterion. Their results demonstrated that the pedestal turbulence has strong impact on ELM dynamics and it is possible to control ELMs by modulating the pedestal turbulence. This work also provides a new framework to explain ELM control methods used in Tokomaks. This work was an invited oral presentation in 2013 APS-DPP meeting and is published on PRL. (P.W.Xi, X.Q.Xu, P.H.Diamond, Phys.Rev.Lett, 112, 085001(2014))。

2.Mr Chenhao Ma, a 2011 grade PhD student, and Dr. Xu deeply studied the turbulence spreading process after ELM crash for the first time. They find that the turbulence in the linear unstable zone can generate perturbations and turbulence in the linear stable zone, because of the radial correlation of the turbulence. This causes the inward front propagation of the MHD turbulence. The turbulence spreading process has a large impact on the total energy loss of an ELM. Because the Landau damping effect is relatively strong on the electron, the ion and electron perturbations have a different cross-phase shift, which yield different responses. When the pedestal pressure is fixed and the pedestal density decreases, the electron temperature perturbation has a large turbulence spreading effect and generate the large electron conducted energy loss, while the ion temperature perturbation almost has no spreading (C.H.Ma, X.Q.Xu, P.W.Xi, et al, Phys. Plasmas, 22, 010702 (2015)). The turbulence spreading effect explains the experimental scaling characteristics of ELM energy losses vs collisionality to a certain extent. Mr Chenhao Ma delivered an invited talk on this in 2014 APS-DPP meeting.

3.Mr Deng Zhao, a 2011 grade PhD student, and Dr. Waltz developed a flux tube nonlinear cyclokinetic code rCYCLO with the parallel motion and variation suppressed. This code dynamically follows the high frequency ion gyro-phase motion (with no averaging) which is nonlinearly coupled into the low frequency drift-waves thereby interrupting and possibly suppressing the gyro-averaging. It also couples the ion temperature gradient (ITG) modes driven by grad-B and collisional fluid electron drift modes to ion cyclotron (IC) modes. As required, rCYCLO cyclokinetic transport recovers gyrokinetics at high relative ion cyclotron frequency (Ω*) and low turbulence levels. However, because the IC modes are stable and act as a turbulence sink, it is found that at high turbulence levels and low-Ω* the cyclokinetic transport is lower (not higher) than the gyrokinetic transport. Further work is in progress with unstable IC modes to explore the possibility of driving cyclokinetic transport higher than gyrokinetic transport.

06 技术物理系 Department of Technical Physics

技术物理系现有教职员工 26 人，其中：教授 6 人，教授级高级工程师 1 人，副教授 8 人，青年千人 1 人，“北大百人计划”研究员 2 人，高级工程师 1 人，讲师 1 人，工程师 5 人。研究方向包括：实验核反应与结构、理论核结构、高能实验物理、中高能核理论、应用核物理、辐射防护、探测器研发、核电子学。拥有一台 2×1.7 MV 串列加速器，主要用于应用核物理研究（离子束技术与应用）；一个亚原子粒

子探测实验室；一个核物理教学实验室；北大 - 兰州联合核物理中心。技术物理系是“核物理与核技术国家重点实验室”的重要组成部分，拥有全国唯一的核物理理科基地和核物理国防紧缺专业；承担 973 项目和多项基金重点项目；拥有广泛的国内外合作，包括：中美“奇特核”理论物理研究所 China-U.S. Theory Institute for Physics with Exotic Nuclei (CUSTIPEN) http://custipen.pku.edu.cn；高能物理方面与欧洲 LHC-CMS 和北京 BEPC-BES 合作；核物理方面与日本 RIKEN-RIBF、兰州 HIRFL 和北京 CIAE 合作等，与日本理化所合建了 Nishina School。

There are 26 faculty members in the department, including 6 full professors, 1 professorship engineer, 8 associate professors, 1 “National Young QianRen Project” research professor, 2 “PKU BaiRen” research professors, 1 senior engineer, 1 lecturer and 5 engineers. The research fields covers experimental nuclear reaction and structure, theoretical nuclear structure, experimental high-energy physics, theoretical intermediate and high-energy physics, applied nuclear physics, radiation protection, detector technique and nuclear electronics. The department is an important part of the State Key Laboratory of Nuclear Physics and Technology, equipped with a facility of 2×1.7 MV tandem accelerator for applied nuclear physics. The department has a subatomic particle detection laboratory, an education laboratory for nuclear physics, and a PKU-Lanzhou joint center for nuclear physics. It is the only department in the universities of China, which is supported by the national project for fostering talents of nuclear science and by the national project of defense in nuclear physics. The researches are supported by 973-project and several key projects from national natural science foundation (NSFC). The department has established many international and national collaborations, including the China-U. S. Theory Institute for Physics with Exotic Nuclei (CUSTIPEN) http://custipen.pku.edu.cn, high-energy physics collaboration with LHC-CMS in Europe and BEPC-BES in Beijing, nuclear physics collaboration with RIKEN-RIBF in Japan, HIRFL in Lanzhou and CIAE in Beijing. An undergraduate education program, named the Nishina School, has also been established with RIKEN in Japan.

一、丰中子核 ^{12}Be 中增强的单极跃迁与集团结构

集团化是一种十分重要的现象，在从天体到基本粒子的许多系统中都有精彩的表现，包括在原子核体系中。传统稳定区原子核结构的基本图像是平均场基础上的独立粒子运动，但在特殊条件下，也表现出集团结构自由度。而在远离稳定线的区域，由于弱束缚和体积膨胀以及与连续态的耦合，集团或分子态结构呈现增强趋势。这会引起原子核性质及其理论描述的根本性变化，也会影响到核技术应用和对核天体演化路径等的认识，因此受到广泛关注。

到目前为止，在稳定核中已经确认了几个集团态，但在不稳定核中，集团态的观察还十分缺乏，仅有的一些结果也往往相互矛盾。实验上准确识别集团结构十分困难，需要同时测定转动惯量（激发能 - 自旋依赖关系）、集团衰变分支宽度、特征跃迁模式等。特别是近年提出的单极跃迁强度，成为识别集团结构的一个敏感观测量。

核物理实验组利用兰州 HIRFL-RIBLL 装置，开展了每核子 29 MeV 的 12Be 的非弹激发和衰变实验。采用近年来发展起来的独特的零度测量技术，发现了在集团分离阈附近 10.3 MeV 处一个很强的激发态。通过碎片角关联确定了这个态的自旋-宇称为 0+（图 1（a）），表明它是此前提出的分子转动带的带首。进一步通过 DWBA 分析（图 1

（b））, 得出这个态的 4He + 8He 衰变道对应的单极跃迁矩阵元为 7.0 +/- 1.0 fm2，显示出典型的集团结构特征。实验同时测得这个态的集团衰变宽度，通过 R- 矩阵分析得出其内在集团结构谱因子为 0.53 +/- 0.10。这些量的测定表明 12Be 的 10.3 MeV 共振态具有典型的集团结构，与采用集团自由度的 GTCM 模型的预言相一致，澄清了十几年来的争论。特别是在不稳定核中首次观察到反常增强的单极跃迁强度，为中子滴线区核的奇特结构研究提供了新的途径。本实验采用的硅微条望远镜集中观察零度附近的衰变，这是发现分离阈附近共振态的关键，将在后续的实验中发挥独特作用。

研究结果发表在最近的《物理评论快报》[Phys. Rev. Lett. 112，162501（2014）]，第一作者为博士研究生杨再宏，通讯作者为叶沿林。此项研究得到 973 计划和国家自然科学基金的资助。

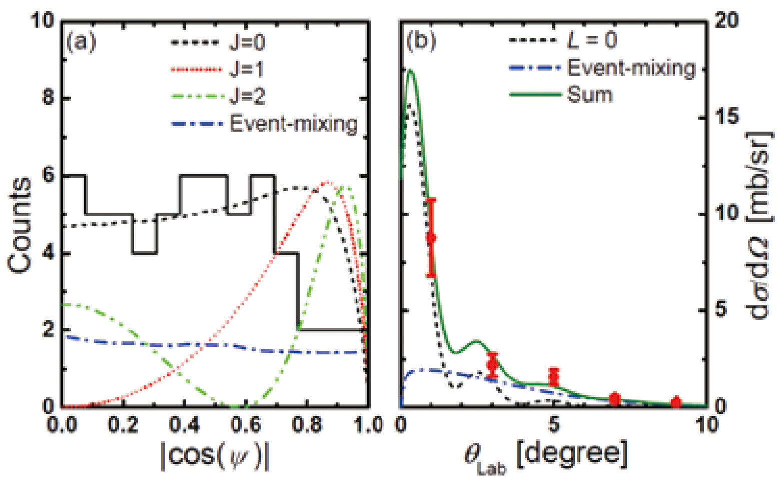


图 1：（a）从 ^{12}Be 的 10.3 MeV 共振态衰变到 4He + 8He 碎片的角关联谱，与理论计算的不同自旋成分和本底成分的角关联谱做比较。（b）^{12}Be 在 C 靶上被激发到 10.3 MeV 态的非弹散射的微分截面；DWBA 计算加上本底谱用来拟合实验数据分布。[图来源于 Phys. Rev. Lett. 112, 162501(2014)].

Figure 1: (a) Fragment correlation spectrum reconstructed from the 4He + 8He decay channel of the 10.3 MeV resonance in ^{12}Be, in comparison to the calculations with various spin components and the even-mixing background. (b) Differential cross sections of the inelastic scattering from a carbon target, which excites the 10.3 MeV state in ^{12}Be; the data are fitted by a DWBA calculation together with a background distribution.

I. Observation of enhanced monopole strength and clustering in ^{12}Be

Clustering is of fundamental importance in structure studies at all levels, from celestial bodies to elementary particles, and appears as intriguing phenomenon in many systems, including nuclide. The stable nuclide is basically described according to the independent particle model, in which the nucleons are moving almost freely in a mean field, although clustering phenomenon may appear in some special cases. But for nuclei far from the β-stability line cluster or molecular structures seem enhanced due most likely to the low-binding energy, size expansion and coupling to the continuum states. This change of the structure degree of freedom would cause dramatic evolution of the nuclear properties and their theoretical descriptions, which may have large impact on the nuclear technique applications and the understanding of the r-process in nuclear astrophysics.

So far the cluster structure has been experimentally identified in several states in stable nuclei, but its observation in unstable nuclei is still very scarce and often under disputing. A clear finding of a cluster state in a nucleus is very challenging, since it requires experimental determination of the excitation energy and spin systematics associated with a rotational band, the cluster decay partial width and the characteristic transition strength. Particularly the monopole transition strength has been proposed as a sensitive probe in featuring the cluster formation.

An inelastic excitation and decay experiment for neutron-rich 12Be at 29 MeV/nucleon was performed by our experimental nuclear physics group at the HIRFL-RIBLL facility in Lanzhou. Thanks to the application of a specially designed 0-degree telescope, a remarkably large peak around 10.3 MeV, just above the cluster separation threshold, is identified. Based on the angular correlation analysis, the spin-parity of this state is determined to be 0+ (Figure 1(a)), being the band head of the proposed molecular rational band. Furthermore according to the DWBA analysis (Figure 1(b)), an enhanced monopole matrix element of 7.0 +/- 1.0 fm2 in the 4He + 8He decay channel is extracted, corresponding to the typical property of the transition among cluster states. In addition this resonant state possesses a large cluster-decay branching ratio, resulting in a large dimensionless reduced width of 0.53 +/- 0.10. These results reveal a typical cluster state in 12Be, in agreement with the GTCM prediction. In particular the observation of the enhanced monopole strength in an unstable nucleus has opened new possibilities for probing exotic structure at the vicinity of the neutron drip-line. Detection around 0-degrees with the silicon-strip telescope is essential in observing the resonance close to the cluster decay threshold. It would be desirable to further apply this method in subsequent similar studies.

The results were published recently in Physical Review Letters 112, 162501(2014) and Sci China-Phys Mech Astron. 57, 1613 (2014). The first author is Zaihong Yang, a PhD candidate at the School of Physics, and the corresponding author is Prof. Yanlin Ye. The work has been supported by the 973 program and the NSFC projects.

二、CMS W 玻色子用于标准模型检验及新物理寻找的研究

W 玻色子是研究电弱相互作用的重要探针，高能实验组在过去的数年里致力于 CMS 实验中 W 探针的研究，作为主要贡献者之一开发了 CMS 实验中的 jet 子结构技术（JHEP 12 (2014) 017）并应用于如下物理研究中：1）重 Higgs 粒子的寻找 当 Higgs 粒子质量较大时（大于～ 600GeV），由于洛伦兹效应，W 玻色子衰变产生的两个喷注会在空间上互相重叠，从而导致原本的两喷注末态重建不准确甚至失败。然而，将重叠的两个喷注当作一个胖喷注来重建，则可以克服以上困难。大横动量且不变质量在 W 粒子静止质量附近的喷注是上述 W 产生的胖喷注的重要候选者。利用发展的喷注梳理技术能够有效的减少实验中多事件堆叠效应对喷注测量结果的影响，而同时开发的子喷注结构技术则通过研究喷注内部粒子的空间和能量分布，可以提供更多区分本底和信号的依据。我们利用 2012 年 LHC 在 8TeV 对撞时获取的 19fb-1 数据，对 600GeV - 1TeV 质量区的标准模型和非标准模型 Higgs 粒子的截面给出了世界最好限制结果 (Eur.Phys.J. C73 (2013) 2469）。2) 引力子的寻找

Randall-Sundrum 模型预言了高质量的 RS 引力子，可以用于解释标准模型中存在的 hierarchy 疑难。对 WW 末态中一个 W 衰变到胖喷注另一个衰变到轻子的过程，我们利用前述的 jet 子结构技术开展寻找 RS 引力子以及其扩展出来的 bulk 引力子的研究，并扩展到寻找一般的高质量共振态。对于 800 - 2500GeV 质量范围的 bulk 引力子，我们的研究给出 70fb - 3fb 的截面限制（JHEP08 (2014) 174）。3）反常四规范玻色子耦合研究　三规范玻色子的联合产生过程对于精确检验标准模型和探寻新物理存在迹象非常重要。 我们选择研究了 WV　 过程，这儿 W 表示末态的一个 W 衰变到轻子，而 V 表示 W/Z 玻色子衰变到夸克，　则表示光子。我们的研究结果给出了 3.4 倍于标准模型截面的上限，这也是世界上标准模型下三规范玻色子耦合的首次测量 (Phys.Rev.D90, 032008 (2014)，图 1)，并对四线顶点反常耦合的相关参数给出了一组世界最严限制。

我们的研究工作得到科技部和国家自然科学基金委员会的大力支持。

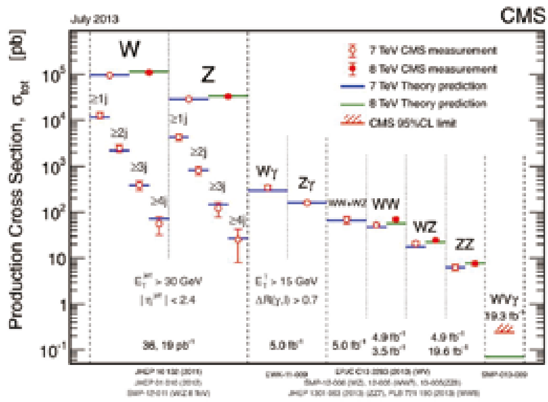


图 1、CMS 通过电弱过程对标准模型的检验 . 图中最右端的三规范玻色子产物截面测量为世界首次测量且为北大高能组完成。

Fig.1 SM Test at CMS via Electroweak process. The production cross-section of triple gauge boson is the world first measurement completed by our group.

II. SM Test and New Physics Search with W Boson at CMS

W boson can serve as an important probe for Electroweak physics. The high energy physics experimental group, as one of key contributors, has developed the jet substructure techniques for boosted W measurement (JHEP 12 (2014) 017), which is now being popularly used in CMS experiment. Our main physics output with W probe can be summarized as following: 1) Search for Heavy Higgs via WW decay The 2 jets decayed from a W boson may merge closely due to Lorentz boost when the Higgs is heavy (>600GeV), which result in that the reconstruction of 2 jets is inaccurate even failed. A new technique, so called jet substructure technique, is developed to solve the problem, which treated 2 jets as one fat jet but kept detail information of its structure, such as spatial and energy distributions. Based on the technique, we analyzed the 19fb-1 pp data collected by CMS experiment in 2012 and published the best constraints on the cross-sections for SM and BSM Higgs in 600GeV – 1TeV mass region (Eur.Phys.J. C73 (2013) 2469). 2) Search for Graviton Randall-Sundrum model introduces heavy RS graviton to solve the hierarchy problem in standard model. WW final states, here one decays to the fat jet (boosted 2 jets) and other to leptons, could be a good measure for RS graviton and extending bulk graviton search as well as for the study on other high mass resonances in general. Our study gave the constraints on cross-section as 70fb – 3fb for bulk graviton in 800 – 2500 GeV mass region (JHEP08 (2014) 174). 3) Study on Anomalous Quartic Gauge Coupling The process with triple gauge bosons in final state is very important for standard model test and new physics. WV　 was chosen by us for the study, here W stands for one W decaying to leptons and V for W/Z to quarks and　 for photon. As of the world first measurement, we published upper limit of the triple gauge coupling cross-section which is about 3.4 times of Standard Model prediction (Phys.Rev.D90, 032008 (2014), Fig.1), meanwhile the most stringent constraints on anomalous quartic gauge coupling. The work is jointly supported by the Ministry of Science and Technology and National Foundation of Science and Technology.

三、 弱束缚原子核的新形态

极不稳定原子核是弱束缚量子多体体系，接近存在阈值，与稳定核相比可能有奇特的结构与动力学特征，如晕结构与软模共振。 极不稳定核是国际国内放射性束流大装置的主要科学目标。 理论研究需要自洽的描述晕分布、连续谱效应、形变、对关联等，这对传统的模型计算是一个很大的挑战。 最近裴俊琛与许甫荣课题组在弱束缚核的新形态探索研究中获得了系列新进展。目前该研究组自己发展的大尺度坐标空间 HFB 模型对于形变弱束缚核的自洽描述的有独特的精度优势。 基于天河一号计算，他们预言了奇特的形状去耦合的晕结构，即有球形核心和形变晕的蛋形晕，并明确分析了共振与非共振准粒子连续谱的贡献，该工作发表在 PRC 快讯 (Phys. Rev. C 87, 051302(2013)

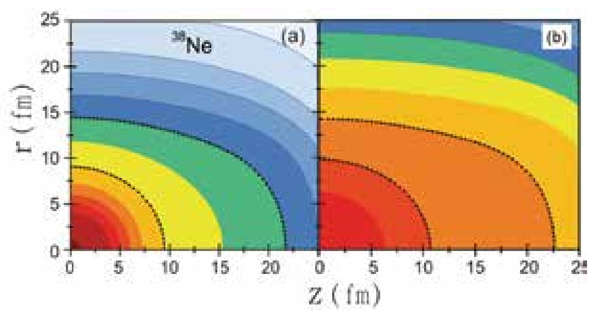


图 1：坐标空间 HFB 计算首次预言出 38Ne 可能有蛋形晕结构（中心部分为球形，外部为形变晕）。(a), (b) 分别为中子晕与中子对密度晕。

Figure 1：HFB calculations in large coordinate spaces firstly predicted an egg-like halo with a spherical core and a prolate halo. (a) neutron halo, (b) n-pairing halo.

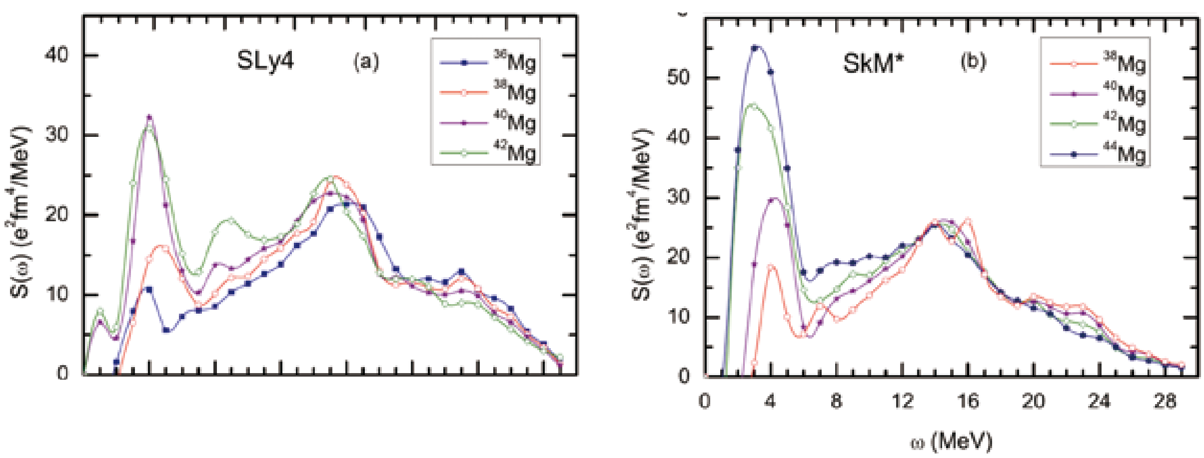


图 2：坐标空间 HFB+QRPA 计算预言的形变晕核 Mg 同位素在接近滴线时在激发能为 4 MeV 时的软单极激发模式。(a), (b) 为不同的核力参数计算。

Figure 2: Coordinate-space HFB+QRPA calculations of deformed halo nuclei, Mg isotopes, can have emergent soft monopole modes around 4 MeV. (a) and (b) are calculations with different Skyrme nuclear forces.

(Rapid Communication))。除了研究基态性质，他们更进一步发展了迭代求解的形变坐标空间 QRPA 模型用于描述形变弱束缚核的动力学。传统的 QRPA 矩阵求解法需要计算海量的矩阵元，而迭代法可以大大减少计算量。在此基础上，他们研究了形变晕的软模单极共振及其集体性，而指出对关联密度晕的振动起主要贡献，这与通常的晕振动图像不一样。该工作也发表在 PRC 快讯 (Phys. Rev. C 90, 051304(2014)(Rapid Communication))。从轴对称形变到三维，计算挑战更大，他们采用多分辨多小波分析方法和混合并行计算在国际上首次实现了三维坐标空间 HFB 方程的求解，可应用于弱束缚核、核裂变、中子星、冷原子气等大尺度的形状复杂的费米子体系描述 (Phys. Rev. C 90, 024317 (2014))。该方法可以大大提高计算效率，是首次应用于核物理，由于这项工作的创新性而入选为编辑推荐亮点文章 (Selected as PRC Editors' Suggestion)。

III. Novel Structures and Dynamics of Weakly Bound Nuclei

Extremely unstable nuclei are weakly bound quantum many-body systems, close to the threshold of existences, and are expected to have exotic structures and dynamics compared to stable nuclei. The study of extremely unstable nuclei has been the hot scientific objective of advanced radioactive nuclear beam facilities around the world. Theoretical studies need to describe properly and self-consistently the halo distributions, continuum effects, deformations and pairing correlations together, which is a challenge to conventional theoretical tools. Recently, the group of Professors Junchen Pei and Furong Xu have made a series of progresses in the exploration of novel structures and dynamics of weakly bound nuclei. They have developed a unique Hartree-Fock-Bogoliubov (HFB) solver in large deformed coordinate spaces, which has advantages in describing weakly bound nuclei. With calculations on Tianhe-1A supercomputer, they firstly predicted an exotic egg-like halo structure, i.e., with a spherical core and a prolate halo, showing the core-halo deformation decoupling. They are able to analyze the continuum contributions. This work has been published in Phys. Rev. C 87, 051302(2013) (R) as a Rapid Communication. In addition to studies of ground states. They have further developed the deformed coordinate-space QRPA method by iteratively solving method, to study dynamics of weakly bound nuclei. The conventional solving method based on the QRPA matrix form needs to calculate huge matrix elements, while the iteratively solving method is much more efficient. Based on this solver, they have studied the soft monopole mode in deformed halo and its collectivity. It has been pointed out that the pairing-density halo vibration is responsible for the emergent soft monopole modes, in contrast to our usual understanding of particle-density halo vibrations. This work has been published in Phys. Rev. C 90, 051304(2014)(R) as a Rapid Communication. From two-dimension (2D) to three-dimension (3D) calculations, the computing challenges are tremendous. They adopted a new numerical method that uses adaptive multi-resolution multi-wavelet analysis and complicated parallel schemes. It is the first time to achieve such 3D coordinate-space HFB calculations, which can be used to study large and complex superfluid Fermi systems such as weakly bound nuclei, nuclear fission, neutron stars, trapped ultracold atomic gases (Phys. Rev. C 90, 024317 (2014)). This novel numerical method is very efficient and has not been applied to nuclear physics before. This work has a good innovation, and the paper was highlighted and selected as an Editors’ Suggestion in Physical Review C.

07 天文学系 Department of Astronomy

北京大学天文学系成立于 2000 年，前身为 1960 年在地球物理系成立的天文专业，2001 年天文学系并入新成立的物理学院。天文学系现有教职工 14 名，其中教授 8 名（包括中国科学院院士 2 名 (兼职), 长江学者特聘教授和讲座教授 2 名，国家杰出青年基金获得者 3 名)，副教授 4 名，办公行政人员 2 名；兼职教授 19 名；博士后 7 名；研究生 50 名，其中博士研究生 49 名，硕士研究生 1 名；本科生 118 名。主要研究领域包括宇宙学与星系形成、高能天体物理、星际介质和恒星与行星系统、粒子天体物理等，涉及各种天文尺度及极端天体环境。

Department of Astronomy of PKU was founded in 2000, based on the Astronomy Division in the Department of Geophysics established in 1960. It became a family member of the School of Physics when the later was created in 2001. The Department of Astronomy have 14 full faculty members consisting of 8 professors, 4 associate professors and 2 secretaries, 19 joint faculty members, 7 post-doctors, 50 post-graduate students, and 118 undergraduates. The main research fields include Cosmology and Galaxy Formation, High Energy Astrophysics, Interstellar Medium, Stellar and Planet System, and Astroparticle Physics, involving astronomical phenomena and astrophysical processes at all scales and various astrophysical environments.

普通星系中发现的第一对超大质量双黑洞

通过和学生及同事合作，我们研究团组最近发现了一对相互绕转的超大质量黑洞。这是首次在普通星系中发现超大质量双黑洞。我们之所以能发现这一现象，是因为这对隐匿的双黑洞最近通过潮汐力撕裂和吞食了一颗恒星，而欧空局的 XMM–Newton X 射线卫星当时恰巧正对准它们所在的方向进行观测。这次发现也验证了我们在 2009 年提出的关于超大质量双黑洞潮汐瓦解的理论预言。这一工作发表在 2014 年 5 月 10 日的 The Astrophysical Journal 杂志上（文献 1）。

一般认为，宇宙中大部分的大质量星系中心存在一个超大质量黑洞。如果能在星系中心发现两个超大质量黑洞，这将改变这一观念并为星系相互并合模型、引力波辐射源的存在提供确凿的证据。因此，搜寻超大质量双黑洞对于我们理解星系演化以及引力波探测问题至关重要。2010 年 6 月 10 日，欧空局的 XMM–Newton X 射线卫星在离我们 20 亿光年的 SDSS J120136.02+300305.5 星系中观测到一次恒星被黑洞潮汐撕裂和吞食事件，并随后用 XMM–Newton 和 NASA 的 Swift 卫星对这一事件进行了后续观测。刚开始，这个星系还一直在向外辐射 X 射线，这一现象看上去和一个超大质量黑洞潮汐瓦解恒星非常相似。但随后的跟踪观测则发现其辐射衰减速率较慢。除此之外，他们还发现了一些奇怪的现象：在发现潮汐瓦解事件之后的 27 到 48 天之间，该星系辐射的 X 射线强度突然降低到卫星可探测极限之下，但之后该星系辐射的 X 射线又能再次被卫星探测到，且强度及其变化和之前预期的结果一致，似乎没有任何的异常。

根据我们的研究，这一人们无法理解和解释的奇怪现象正是我们早在 2009 年就预言的超大质量双黑洞独有的观测特征。根据我们的预言，当双黑洞系统发生对恒星的潮汐瓦解事件时辐射会交替出现变弱（消失）以及复原的现象，这是因为流向一个黑洞的恒星碎片流会受到另一黑洞引力的影响而发生中断，从而使得系统暂时因供能不足而无

法向外产生足够强的 X 射线辐射（图 1）。我们发现有两种可能的双黑洞系统可以产生 J120136 的观测现象。第一种情况是一个大约 100 万个太阳质量的黑洞围绕另一个质量为 1 千万个太阳质量的主黑洞作椭圆轨道运动。另一种情况是主黑洞质量也是 100 万个太阳质量，且两者作圆轨道运动。两种情况下黑洞之间的距离都必须很小，大概是千分之二光年（约我们太阳系的宽度）。对于新发现的这对距离如此近的黑洞系统，他们将通过引力波向外辐射轨道能量，然后慢慢缠绕在一起，并在大概 200 万年之后并合形成一个单黑洞。

参考文献：

1、Liu, F. K.; Li, Shuo; Komossa, S., “A Milliparsec Supermassive Black Hole Binary Candidate in the Galaxy SDSS J120136.02+300305.5”, 2014, ApJ, 786, 103

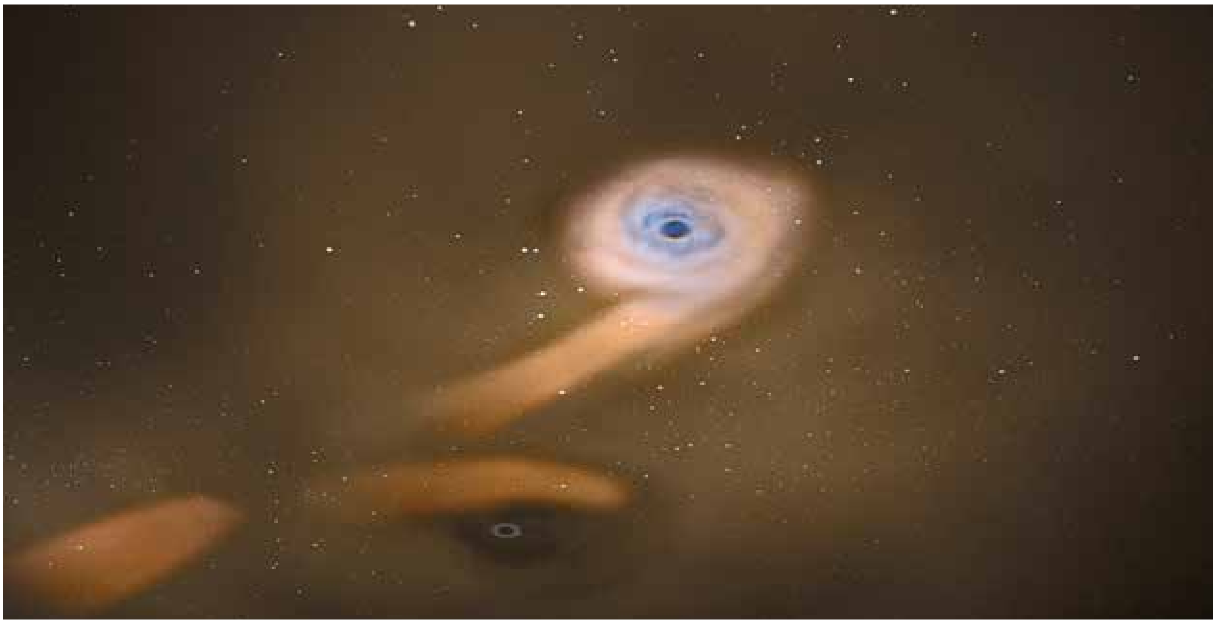


图 1 这次发现的超大质量双黑洞系统示意图。 (ESA, C. Carreau)

Unique Pair of Supermassive Black Holes Discovered in an Ordinary Galaxy

With my students and colleagues, we recently discovered a pair of supermassive black holes in orbit around one another. This is the first time such a pair have been found in an ordinary galaxy. We discovered them because they ripped apart and accreted a star when the European Space Agency’s space observatory XMM–Newton happened to be looking in their direction. The finding also validates our predictions from 2009 of the tidal disruption by supermassive binary black holes. Our results were published in the 10 May 2014 issue of The Astrophysical Journal (Reference 1)

Most massive galaxies in the Universe are thought to harbor one supermassive black hole at their center. Two supermassive black holes are the smoking gun that the galaxy has merged with another and the strong gravitational wave radiation sources are present in the universe. Thus, finding binary supermassive black holes can tell astronomers about how galaxies evolved into their present-day shapes and sizes.

On 10 June 2010, a tidal disruption event was spotted by XMM–Newton in the galaxy SDSS J120136.02+300305.5, approximately 2 billion light years away. Follow-up observations just days later were carried out with XMM–Newton and NASA's Swift satellite. The galaxy was still spilling X-rays into space. It looked exactly like a tidal disruption event caused by a supermassive black hole, but as they tracked the slowly fading emission day after day, something strange happened. The X-rays fell below detectable levels between days 27 and 48 after the discovery. Then they reappeared and continued to follow a more expected fading rate, as if nothing had happened.

Our recent work showed that this "strange" behavior is exactly what we predicated in 2009. My group had been working on models of black hole binary systems that predicted a sudden plunge to darkness, followed by a recovery because the gravity of one of the black holes disrupted the flow of gas onto the other, temporarily depriving it of fuel to fire the X-ray flare (Figure 1). We found that two possible configurations could reproduce the observations of J120136. In the first, the primary black hole contained 10 million solar masses and was orbited by a black hole of about a million solar masses in an elliptical orbit. In the second solution, the primary black hole was about a million solar masses in a circular orbit. In both cases, the separation between the black holes was relatively small: about 2 thousandths of a light year. This is about the width of our Solar System. Being this close, they will radiate their orbital energy away through gravitational waves, gradually spiralling together, until in about two million years time they will merge into a single black hole.

08 大气与海洋科学系 The Department of Atmospheric and Oceanic Sciences

北京大学大气与海洋科学系有着悠久的历史和优良的传统，大气科学最早源于 1929 年在清华大学建立的气象学专业。在经历了 1938-1945 西 南联大的艰苦岁月之后，于 1946 年在清华大学成立了气象系。1952 年，全国院校调整，清华大学气象系的师生并入北京大学物理系成为气象专业。1958 年，北京大学成立地球物理系，气象专业扩展为该系的大气物理和天气动力两个专业。1998 年，大气物理和天气动力两个专业合并为大气科学专业。2001 年 北京大学成立物理学院，大气科学专业进入物理学院，建立大气科学系。2010 年，北京大学决定在大气科学系建立物理海洋专业，并将大气科学系更名为大气与海洋科学系。

大气与海洋科学系拥有一支优秀的教师队伍。现有教职员工 31 人，教授 12 人 (其中中科院院士 1 人，国家千人计划讲座教授 1 人，国家杰出青年 1 人），青年千人计划 1 人，北京大学百人计划研究员 5 人（其中杰出青年 1 人、优秀青年 2 人），副教授和高级工程师 9 人，讲师 2 人，另有兼职教授 5 人。近几年来，一些国外优秀青年人才回国任教，使教师队伍充满了生机和活力。近几年来，每年科研经费达 1600 万元，每年发表 SCI 论文近 60-70 篇。目前，我系教师的主要研究领域有：大气辐射与遥感、云物理与大气化学、

大气边界层与环境、数值天气预报与模拟、大气动力学和非线性动力学、气候动力学与模拟、物理海洋、海 - 气相互作用与气候变化、行星大气和气候等。

The Department of Atmospheric and Oceanic Sciences at PKU celebrates a long and prestigious heritage. Our Atmospheric Science Program traces its root back to the Meteorology Program originally founded in 1929 at Tsinghua University. After the period of the utmost fortitude at the National Southwest Associated University during World War II (1938-1945), the Department of Meteorology was established at Tsinghua University in 1946. In 1952, the faculty and students of the Department of Meteorology were all moved from Tsinghua University to the Department of Physics of Peking University, as part of the nation-wide restructuring of higher education. In 1958, Peking University established the Department of Geophysics, under which the Program of Meteorology expanded into two programs: Atmospheric Physics and Dynamical Meteorology. The two programs combined to form the Program of Atmospheric Sciences in 1998. In 2001, Peking University established the School of Physics, into which the Program of Atmospheric Sciences was incorporated to become the Department of Atmospheric Sciences. Most recently, Peking University founded the Program of Physical Oceanography under the newly renamed Department of Atmospheric and Oceanic Sciences in 2010.

The Department of Atmospheric and Oceanic Sciences has a strong faculty team. There are currently 31 faculty and staff members, including 12 full professors, 1 Young Qianren professor, 5 Peking University “Bairen” Research Scientist, 9 Associate Professors and Senior Engineers, 2 Lecturers, and 2 staff. In addition, there are also 5 adjunct professors. More and more outstanding and internationally-trained young scientists are joining the Department in the past few years, invigorating our faculty team. In recent few years, we have received more than 16 million RMB per annum in research funding and have published approximately 60-70 SCI journal papers each year. Main research areas of our faculty currently include: atmospheric radiation and remote sensing; cloud physics and atmospheric chemistry; atmospheric boundary layer and environment; numerical weather prediction and simulation; atmospheric dynamics and non-linear dynamics; climate dynamics and modeling; physical oceanography, air-sea interaction and climate change, planetary atmospheres and climate, etc.

一、太阳系外行星气候和宜居性

地球生命在宇宙中是否是唯一的？太阳系外是否存在适宜生命存在的星球？一直是人类不断思考和探索的问题。目前，公认的适宜类似地球生命存在的最关键的条件是液态水。因此，判断一颗行星是否是适宜的条件是其表面温度是否能够保证液态水的长期存在，其表面温度应介于大约 0-70 °C 之间，低于 0 °C，水完全被冻结；高于 70 °C（不需要达到 100 °C），行星将进入温室逃逸状态，其表面液态水将完全被蒸发，并最终被光解（太阳系的金星很可能在早期经历了温室逃逸，现在没有液态水）。

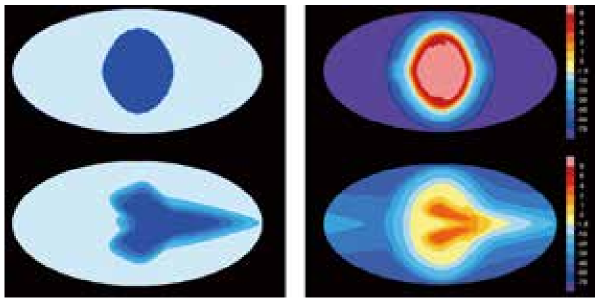
物理学院大气与海洋科学系胡永云教授和杨军博士的研究目标是红矮星附近的宜居行星。这是因为红矮星是宇宙中数量最多的恒星（占恒星总数量的大约 80%），而且，因为红矮星的辐射温度较低，宜居行星距离其母星较近，易于被探测到，因此，人类很可能首先在红矮星附近发现宜居行星。但由于红矮星与其宜居行星太近，强的引力造成宜居行星被潮汐锁相，也就是行星的一面永远面对红矮星（永久白天），而另一面永远背对红矮星（永久黑夜），这势必造成行星的朝阳面和背阳面之间的加热不均匀。由此而产生的一个严重的问题是，

行星朝阳面温度适于液态水存在，但其背阳面由于极端寒冷有可能使所有的大气和水分都被冻结在背阳面，从而不适宜生命存在。

针对该问题，胡永云教授和杨军博士首次强调了海洋热量输送对锁相行星气候和宜居性的影响。使用海 - 气耦合气候模式，他们进行了两种数值模拟试验：1）静止的海洋（无海洋热量输送）；2）动态的海洋（有海洋热量输送）。在静止海洋条件下，行星朝阳面只有部分区域存在液态水（蓝色），其它区域均为海冰所覆盖（白色），背阳面地表温度在 -70 °C 以下。如果考虑海洋流动，开放海域不再是圆形，而是类似于“龙虾”状，两只“钳子”对称地位于赤道两侧，长长的“尾巴”一直延伸到背阳面。当 CO_2 浓度足够高时，背阳面的海洋也将被全部融化。

他们认为，如果考虑了海洋热量输送，不仅大气不会在背阳面坍塌，水分也不会在背阳面冻结。上图的气候空间模态将有助于识别系外行星是否是宜居的。虽然目前的观测技术还无法做到这一点，但计划中的太空望远镜将很有希望达到这一目标。他们的代表性研究成果发表在美国科学院院刊（PNAS），该结果对认识系外行星适宜生命存在的可能性以及未来探测适宜生命存在的行星有着极为重要的理论意义。

论文全文可见：http://www.pnas.org/content/early/2013/12/26/1315215111.full.pdf+html



图：气候模式模拟的海冰覆盖率（左）和温度分布（右）。上图：静止的海洋。下图：动态海洋。左图中的蓝色表示开放海域，白色表示冰封海域。右图的彩色标尺单位是° C。恒星的直射点在图的中心。

Figure caption: Simulation results of sea-ice coverage (left) and surface temperature (right). Upper maps are for the case of a slab ocean, and the lower maps are for a dynamic ocean. For left-hand maps, blue indicates open ocean, and gray denotes ice. For the right-hand maps, the unit of temperature color bars is ° C.

I. Exo-oceanography, climate, and habitability of tidal-locking exoplanets around M-dwarfs

Are we alone in the Universe? Are there any other extra-solar planets (exoplanets) which can harbor Earth-life-like life? These have lone been intriguing questios that human wish to answer. So far, the most critically necessary condition for life is liquid water. Thus, the criterion for judging whether an exoplanet is habitable is whether its surface temperature allows the existence of liquid water, that is, whether its surface temperature is in the range of 0 – 70 °C. If it is below 0 °C, all water is frozen. If it is higher than 70 °C, the exoplanet would run into runaway climate state, and all water is evaporated and photo-dissociated.

Professor Yongyun Hu and his former PhD student, Jun Yang (currently a postdoctoral research scientist at the University of Chicago), from the Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, has recently studied the problems and made outstanding contribution to this subject. In this work, they have demonstrated the importance of exo-oceanography in determining climate states, habitability and the width of the Habitable Zone around M-Dwarf stars.

M-dwarf stars are the most common type of stars in the Universe. It is thus very likely that habitable exoplanets are first discovered around M Dwarfs in future. Climate patterns caused by ocean circulations, as shown in this study, may have observational consequences in both the infrared and visible phase curves of the system, which could be visible in future observational missions. The habitable zone around M stars is close to such stars because of their weak luminosity. In consequence habitable planets orbiting M-type stars are likely to be tide-locked to their primary. Yongyun Hu and Jun Yang carried out the first simulation of this problem with a fully coupled dynamic ocean-atmosphere model, and found that ocean heat transports substantially extend the area of open water along the equator, and can even lead to complete deglaciation of the nightside. They demonstrated further that when ocean heat transports are taken into account, open water can be maintained near the substellar point even in the outer reaches of the habitable zone, and even at very low atmospheric concentrations of CO2. This study provides the first demonstration of the importance of exo-oceanography in determining the habitability state of an exoplanet.

The attached figure here compares sea-ice coverage and surface air temperatures between two-types of simulations: slab ocean and dynamic ocean. With a slab ocean, the open-ocean region is a round area, while all rest parts are covered by ice and nightside temperature is below -70 °C. The exoplanet looks like an "Eyeball". In contrast, as a dynamic ocean is included to the model, the spatial patterns of both open-ocean and warm surface temperatures are like a "Lobster", with two "claws" at both sides of the equator and a long tail along the equator, which extends to the nightside. Moreover, the nightside surface temperature greatly increased due to ocean heat transport from the dayside to the nightside.

Their paper, entitled "Role of ocean heat transport in climates of tidally locked exoplanets around M-dwarf Stars", has been published in Proceedings of the National Academy of Sciences (PNAS) in January, 2014. Their results have important implications to understand the habitability and climates and to future detection of habitable exoplanets.

Open access is at: http://www.pnas.org/content/early/2013/12/26/1315215111.full.pdf+html

二、国际贸易对全球大气环境的影响

产品生产和消费及其相关的交通运输、电力生产等经济活动导致大量的排放，造成全球大气污染。由于大气输送，国际上十分重视他国排放的污染物对本国的影响，但是这方面的研究和谈判都是从产品生产的角度，认为只要产品生产是在某国进行，相应的污染物排放就归属于该国，而不考虑该产品是否被该国消费。通过国际贸易，某国消费的产品可以从他国进口，因此产品的产地及相应的污染排放地从消费国转移到出口国，改变了全球污染排放的空间分布。由于各国工业结构、能源结构、排放控制等方面的差异，生产同一产品导致的排放量也可能有很大区别，因此国际贸易可影响全球排放总量。污染物的生命周期较短，因此排放总量和空间分布的变化必然意味着国际贸易对全球和区域大气环境产生重要影响。目前这方面的研究几乎是空白。

林金泰研究员和本科生潘达领衔的国际合作研究在 PNAS 发表（China's international trade and air pollution in the United States, PNAS, doi:10.1073/pnas.1312860111, 2014），基于中国的国际贸易，

研究国际贸易的相关经济活动对全球大气污染和传输的影响。从产品消费的角度，分析 2000 至 2009 年间与中国国际贸易相关的直接和间接经济活动（生产、运输、发电等）导致的大气污染，发现仅 2006 年中国东部地区近地面硫酸盐颗粒物有 23-34% 来自与产品出口相关的经济活动，而碳和一氧化碳的相应比例为 10-23% 和 12-23%（图 1c,d），发现产品出口美国导致的污染占出口相关总污染的 21%。

研究发现与中国出口相关的污染物可通过大气输送影响美国，如 2006 年美国西部地区近地面硫酸盐和臭氧分别有 3-10% 及 0.5-1.5% 与中国出口的相关排放及传输有关（图 1a,b）。美国从中国进口产品而减少美国排放，但增加了中国的污染排放和大气传输，其净效果是中国地区和美国西部的硫酸盐污染增加而美国东部的污染减少了（图 2a）。由于美国东部人口密度远大于西部，因此美国从中国进口产品而减少本国生产有利于其国民整体健康水平。若美国通过加强技术支持等手段帮助中国减排，不仅能改善中国的空气质量，同时也能降低美国西部的污染。因此，对国际贸易的相关环境影响的评估有益于增强国际交流和协作，减少全球污染排放和传输。

该研究获得 PNAS 的 2014 年度 Cozzarelli Prize（该奖从 3000 多篇 PNAS 论文中选取 6 篇）。

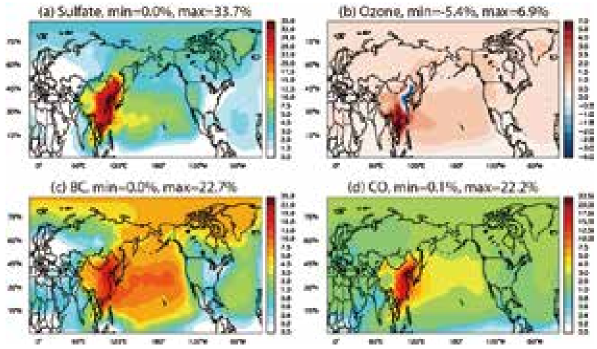


图 1：2006 年中国产品出口的相关污染物及前体物排放对北半球近地面大气中的污染物浓度的百分比贡献：（a）硫酸盐颗粒物，（b）臭氧，（c）碳颗粒物，（d）一氧化碳。

Fig. 1: Simulated percentage contribution of surface air pollution in 2006 from Chinese export-related emissions for (a) sulfate, (b) ozone, (c) black carbon, and (d) carbon monoxide.

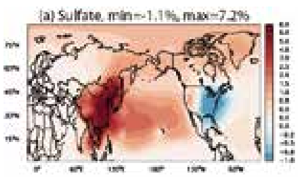


图 2a：2006 年美国从中国进口产品与自身生产相应产品相比，对北半球近地面大气中的硫酸盐颗粒物浓度的百分比影响。

Fig. 2a: Simulated percentage change in 2006 surface sulfate pollution due to Chinese export of goods to the United States versus producing the same goods in the United States.

II. Influences of international trade on global atmospheric environment

Production of goods for consumption and associated economic processes (transportation, power generation, etc.) result in tremendous amounts of air pollutant emissions with a profound impact on regional air quality and global atmospheric pollution transport. Transboundary pollution transport is of serious concern for air quality globally. The United States has a particular interest in understanding the impacts of trans-Pacific transport of air pollution from China and other Asian countries, and much research has been conducted in this regard. However, previous research on air pollution transport and source attribution has been based on a so-called production-based accounting approach, where pollutant emissions related to production of goods are attributed to the country producing the products, no matter whether the products are consumed in the same country or are exported to supply foreign consumers.

International trade allows a country to import goods from other countries; therefore it alters the location of production and thus affects the spatial distribution of emissions. Also, the amount of emissions from production of a particular product differs significantly between countries, due to differences in economic structure, energy structure and emission control levels. This might greatly change the total amount of global emissions. Changes in both magnitude and spatial distribution of emissions will lead to substantial changes in regional air pollution and global transport, due to the relatively short lifetimes of air pollutants (from several hours to several months). Through these mechanisms, international trade has a profound impact on the global atmospheric environment. However, research has rarely been done in this regard.

Professor Jintai Lin and undergraduate Da Pan led an international collaborative study to analyze the impacts of China's international trade on the global atmospheric pollution and transport (China's international trade and air pollution in the United States, PNAS, doi:10.1073/pnas.1312860111, 2014). Instead of adopting the traditional production-based pollution analysis, the team examined the trade influences from the consumption perspective. The team calculated the emissions between 2000 and 2009 related to China's exports and imports through an economic input-output analysis and emission statistics. The study revealed that, for 2006 alone, as much as 36% of sulfur dioxide, 27% of nitrogen oxides, 22% of carbon monoxide and 17% of black carbon in Chinese anthropogenic emissions were related to production of goods for export. For each pollutant, 21% of the export-related emissions were tied to China-to-U.S. export. The total amounts of export-related Chinese emissions were larger than emissions in foreign countries related to China's imports by a factor of 4-6. Using a global atmospheric chemical transport model called GEOS-Chem, the team further revealed that in 2006, 23-34% of sulfate particulate concentrations in the surface atmosphere of East China were caused by export-related emissions (Fig. 1a). The fractions were about 10-23% for black carbon and 12-23% for carbon monoxide (Fig. 1c,d).

The study further showed the impacts of China's export-related pollution on the global atmospheric environment, with a particular focus on air quality in the United States. The study showed that in 2006, about 3-10% of sulfate and 0.5-1.5% of ozone in the surface atmosphere of the western United States were tied to China's export-related emissions (Fig. 1a,b). The U.S. outsourcing manufacturing to China reduced emissions produced in the United States with a significant increase in emissions produced in China and thus an increase in pollution transported from China. The two factors compensated for each other, resulting in an improvement in sulfate air quality over the eastern United States with reductions in China and the western United States (Fig. 2a). The changes in U.S. air quality were overall beneficial for the United States due to the much denser population in the east. Enhancing China's energy efficiency and emission control technologies to the U.S. level (e.g., through enhanced technology exchange) would not only reduce Chinese air pollution but also improve air quality in the United States.

The study concluded that analysis of the trade impacts on the global atmospheric environment with a consumption-based accounting would facilitate discussions of international collaboration in reducing global air pollution and transboundary transport. The paper has been awarded the 2014 PNAS Cozzarelli Prize. The annual prize is given to six papers "of outstanding scientific excellence and originality", out of a total of ~ 3500 PNAS papers.

三、冰消期以来的厄尔尼诺变化

厄尔尼诺是赤道中 - 东太平洋每隔 2-7 年就会发生一次的、可长达一年之久的海温升高现象，在年际尺度上是影响地球气候系统的“心跳”。每当厄尔尼诺发生时，中 - 南美洲太平洋沿岸地区和全球范围都会发生显著的气候异常，甚至出现严重的灾害。但科学家们仍然不清楚厄尔尼诺对主要外部气候强迫（如轨道要素、淡水通量、冰盖、温室气体等）的响应机理。

物理学院大气与海洋科学系刘征宇、陆正遥、闻新宇组成的团队及其合作者使用气候模式模拟了过去 21000 年厄尔尼诺的变化情况，并与已有观测资料进行对比，揭示了地球轨道变化和淡水通量变化对冰消期以来 El Niño 变化起着决定性作用。结果表明：在轨道时间尺度上，轨道要素（特别是岁差）通过热带海 - 气耦合反馈作用决定了厄尔尼诺的强度，这种机制在全新世表现得尤为明显，能很好地解释已有的观测证据(图中的 a 灰线和 f)；在千年尺度上，北大西洋淡水通量通过影响大西洋热盐环流和太平洋赤道年循环来影响厄尔尼诺的变率，该机制在冰川消融期表现相对显著（图中的 b、c 和 e）。

这项研究的意义体现在两个方面：对现代气候而言，为人们在全球变暖的背景下判断厄尔尼诺的长期变化趋势提供了更宽广的科学视角；对古气候而言，这项工作为如何利用数值模式统一和解释已有的、分散的观测证据指明了方向，是利用超长时间连续气候模拟进行气候变率机理研究的重大突破，为今后古 ENSO 领域新观测证据的发掘和数值模拟研究建立了重要的参照标准。

论文：

Z Liu, Z Lu, X Wen, et al. Evolution and forcing mechanisms of El Niño over the past 21,000 years. Nature 515,550-553 (2014) doi:10.1038/nature13963

http://www.nature.com/nature/journal/v515/n7528/full/nature13963.html

Nature 配发的新闻评论：

http://www.nature.com/nature/journal/v515/n7528/full/515494a.html

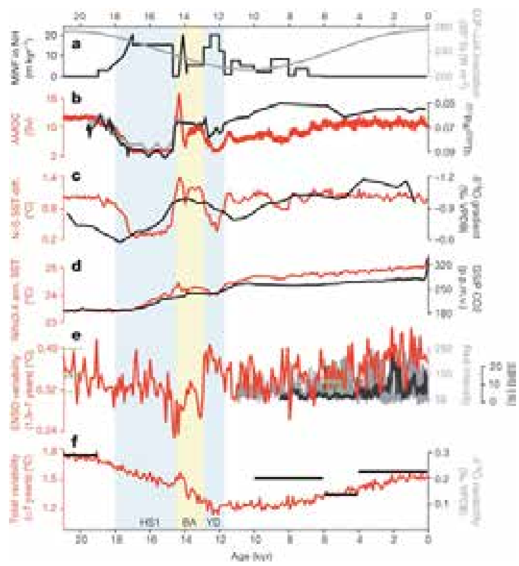


图 1：21000 年来主要气候强迫的变化和厄尔尼诺的响应。a) 北大西洋淡水通量（黑线）与南纬 30 度冬 - 夏太阳入射能量的差异（灰线）；b) 北大西洋经向翻转流（红线）与百慕大地区 231Pa/230Th 比值（黑、灰线）；c) 东太平洋经向海温差（红线）与氧同位素记录（黑线）；d) Nino3.4 区的海温指数（红线）与 CO2 重建序列（黑线）；e) 厄尔尼诺年际振幅（红线）以及东太平洋（黑线）和南美沿岸（灰线）的湖泊沉积记录，绿线是 PMIP 计划模拟结果的范围；f) Nino3 区海温 7 年以下的总变率，黑线是东太平洋沉积记录的总变率。

Figure 1　TRACE simulation and observation during the last 21,000 years. a, Grey, amplitude of annual cycle of insolation (DJF–JJA) at 30S; black, meltwater flux into the North Atlantic. b, Red, AMOC transport; black and grey, 231Pa/230Th ratio in Bermuda. c, Red, eastern Pacific north–south difference in annual SST; black, reconstruction. d, Red, Nino3.4 annual SST; black, Nino3.4 CO2 reconstruction. e, Red, ENSO amplitude in 100-year windows; black, lake sediment records in the eastern Pacific; grey, lake sediment records on the South American coast. f, Amplitude of Nino3 SST total variability in 100-year windows. The black bars show the reconstruction of total SST variance derived from sediment cores in the eastern equatorial Pacific.

III. Evolution of El Niño since Last Glacial Maximum

El Niño, a climatic anomalous phenomenon occurring over the eastern equatorial Pacific Ocean every 2-7 years with 1-year warmed water at sea surface, play the key role in modulating Earth’s climate on the inter-annual timescale. El Niño cause wide and unusual climatic disasters near South America, Australia, and even the coasts surrounding the entire Pacific. However, one still do not understand why El Niño behaves like this especially as the responses to key external forcing including orbital parameters, fresh water fluxes, ice sheet, and green house gases.

Dr. Zhengyu Liu and his team at Peking University investigated the relationship between modeled El Niño and the observational records during the last 21,000 years. Liu and his collaborators performed a set of long-term transient climate simulations covering the last 21,000 years using coupled climate model, and compared the model results with various proxy data. It is indicated that both the orbital parameters, particularly the procession, and melting water flux dominate El Niño’s responses. On the low-varying orbital timescale, El Niño was controlled by orbital forcing through complex tropical air-sea feedbacks, which is especially evident during the Holocene, when most of the observations can be explained (Fig 1). On the fast-varying millennial timescale, however, the melting water flux injected into North Atlantic affect El Niño’s variability in the deglaciation mainly by tuning the meridional overturning circulation of North Atlantic and the annual cycle pattern over the equatorial Pacific.

The present study provides the climate community a wide view of showing how El Niño will behave as the responses to key climatic forcing, and exhibits meaningful thoughts for future climate projection under the context of global warming. In the meanwhile, one good model in paleoclimate studies was set up in terms of performing long-term transient simulations and model-data comparison especially in the paleo-ENSO community.

09 普通物理教学中心 Teaching Center of General Physics

北京大学物理学院普通物理教学中心是北京大学物理学院下属的一个三级机构，其前身为北京大学物理系普通物理教研室，负责普通物理各类课程的长期建设、教学研讨活动和对外教学交流活动的组织以及教学日常组织管理工作。中心下设一个演示实验室和 10 个主干基础课课程组，每个课程组设课程主持人和主讲人，中心的主要任务是承担全校普通物理 01 — 05 共五个系列平台课程的教学任务，授课对象为理科将近 2000 学生，年授课工作量约 222000 人学时。

普通物理教学中心努力传承北大普物教学的优良传统，初步形成了一支专任和兼任相结合，科研与教学相结合，老、中、青教师相结合的与北大地位相称的普物教学团队，团队的职称结构和年龄结构合理，专业分布广泛，团队规模适度，结构优化，学术水平高，教学质量好。

The Teaching Center for General Physics is a branch of School of Physics at Peking University. Previously, it was called the Teaching and Research Section of the Physics Department. The main task of the Center is to supervise all the teaching programs of general physics courses, such as mechanics, electrodynamics, thermodynamics and optics, for the sciences major undergraduate students of Peking University. It is also responsible for organizing seminars and arranging foreign exchange activities, which are closely related to teaching and learning. All the members of the Teaching Center have full teaching load each semester. They are heavily involved in making and managing the entire teaching schedule at School of Physics, too. The Teaching Center has one laboratory for demonstration and 10 teaching groups. Each of them is led by a moderator and is dedicated to teaching a specific subject. Their duties cover the whole Physics 01-05 series. Each year, more than 2,000 undergraduate students take these courses. It is equivalent to a working load of 222,000 teaching units (number of students times class hours) per year.

Since its establishment, the Center has set very high standards for each course and made great effort to achieve teaching excellence, as the Teaching and Research Section of the Physics Department did traditionally in the old days. As far as the teaching faculties are concerned, except several full-time members, many professors from other departments of School of Physics participate also in teaching general physics. Since these lecturers are experienced researchers, they make their classes more interesting and illuminating to the students. On the other hand, the Center invites also some retired teachers to be senior advisors. Therefore, each teaching group has an ideal structure with respect to the distributions of faculty ages, specialties, professional ranks and teaching experiences. These teams perform at very high professional levels which are compatible with the academic stature of School of Physics at Peking University. The Teaching Center for General Physics is dedicated to sustain such high teaching standards in future.

《电磁学》、《光学》作为国家级资源共享课上线，先修课电磁学在 coursera 网站上线

普通物理教学中心最近两年内在课程建设方面取得了阶段性成果。

2013 年度普物教学中心负责的两门国家精品课《电磁学》和《光学》通过升级改造，将国家精品课的课堂实时录像、相应的 ppt 文件、知识点解释以及教学指导等教学资源整理加工，通过严格审查后，获得国家级资源共享课资格并在在爱课程网站上线。资源共享课《电磁学》负责人是普物教学中心教授王稼军，团队成员有陈晓林、沈波、王福仁和穆良柱。资源共享课《光学》负责人钟锡华，团队成员有王若鹏、陈志坚、李焱、王树峰、曲波。目前两门课已经在爱课程网站上线，可以提供校内外学生学习网上学习和参考，网址是 http://www.icourses.cn/mooc/。

2013 年 1 月，北京大学正式宣布应全国部分中学要求，与中学合作试点开设“中国大学先修课程”。由普物教学中心王稼军教授作为主持人向中学推出先修课《电磁学》，这是北京大学向中学生首次开出的五门先修课之一，主要提供给少数学有余力对物理特别感兴趣的中学生选修。希望中学生可以通过先修《电磁学》得到一定的训练，领略大学的教学理念，锻炼自学能力。目前已经进行了三次先修课考试，有将近 1000 位中学生参加了考试，平均优秀率为 5%。

慕课是近年来教育界的一件新生事物，美国两大慕课平台 coursera 和 edx 与北京大学合作，发展和建设慕课。到目前为止，北京大学共建设了 35 门慕课。王稼军教授将先修课改造成慕课，2014 年 9 月 15 日开始上线于美国 coursera 慕课平台，网址是 https://www.coursera.org/，首次开课约有

3600 人注册。电磁学慕课团队由王稼军、穆良柱和博士研究生安炜组成，王稼军负责视频、ppt 文稿，穆良柱负责练习题编写，安炜博士负责全部资料上载和与学员联络。在团队成员的通力合作下，完成了一学期 13 周的课程，练习测试和考试。下学期将在 coursera 重开此课。团队将进一步完善，并将努力作反转课堂的尝试。

Electromagnetism and Optics were approved for The Chinese University Open On-line Excellent Courses program and Electromagnetism was opened on-line to high school students

In the year of 2013, two courses of the Teaching Center for General Physics, Electromagnetism and Optics were approved by the Chinese Education Ministry for the ZGDXZYGX (The Chinese University Open On-line Excellent Courses) program. In the past two years, the faculty members at the Teaching Center for General Physics made great efforts to improve teaching quality of general physics by exploiting opportunities provided by Internet. Several years ago，these courses were recommended as GJJPK courses (The National Excellent Courses) by the Education Ministry. This time, we made first both the courses video-taped. Then, after carefully editing and revising, we up-loaded these tapes with supplementary materials, such as the power-point files and additional explanatory documents onto the ZGDXZYGX courses website http://www.icourses.cn/mooc/. Personally, Professor Wang Jia-Jun was in charge of upgrading the course Electromagnetism. She was aided by Professors Chen Xiao-Lin, Shen Bo, Wang Fu-Ren and Mu Liang-Zhu. Professor Zhong Xi-Hua was in charge of upgrading the course Optics. He was aided by Professors Wang Ruo-Peng, Chen Zhi-Jian, Li Yan, Wang Shu-Feng and Qu Bo.

In the meantime, Professor Wang Jia-Jun opened an on-line course Electromagnetism to high school students, too. At the beginning of 2013, in response to the appeals of some high school principals, the authority of Peking University decided to provide the Chinese Advanced Placement Courses to the students of these high schools. The main purpose of this program is to help some advanced students on studying mathematics and physics by themselves. Electromagnetism is one of the first five courses approved by the University. Up to now, it has held three examinations. About 1,000 students took these examinations and five percent of them obtained score A. Furthermore, Professor Wang made also this course into a MOOC (Massive Open On-line Courses). Recently, COURSERA and EDX, the two major MOOC platforms based in USA have made agreements with Peking University, respectively. With their help, the University has opened 35 MOOCs (https://www.coursera.org/), including the course of Electromagnetism. In the fall semester of academic year 2014-15, 3,600 students all over the world enrolled in this course of 13 weeks. During the teaching period, Professor Wang was aided by Dr. Mu Liang-Zhu in making quiz problems and by Mr. An Wei in uploading course materials and communicating with students. This course will be taught again each semester. We hope that it will eventually play a complementary role to the conventional classroom teaching of Electromagnetism.

10 基础物理实验教学中心 The Teaching Center for Experimental Physics

北京大学基础物理实验教学中心是“国家级实验教学示范中心”，承担国家级精品课“普通物理实验”和“近代物理实验”的基础课教学，并开设研究型的“综合物理实验”选修课。目前在岗专职教师 9 名（教授 2 名，副教授 5 名，讲师 2 名），实验技术人员 6 名（高级工程师 1 名，工程师 5 名）。

The Teaching Center for Experimental Physics at Peking University is a national demonstration center of experiment teaching. It is mainly engaged in teaching of “General Physics Experiment” and “Modern Physics Experiment”, which are of high-quality nationwide and belong to “National Outstanding Courses”. Besides, the center gives a research course called “Comprehensive Physics Experiment” to students who are willing to investigate some experimental problems. Now there are 15 faculty members in the center, in which are 2 professors, 5 associate professors, 2 lecturers, 1senior engineer, 5 engineers。

非线性热对流斑图测试仪荣获第三届全国高等学校自制实验教学仪器设备评选一等奖

2014 年 11 月，物理实验教学中心研制的“NTCPI—Ⅰ型非线性热对流斑图测试仪”在中国高等教育学会秘书处和教育部高等学校实验室建设指导委员会、教育部高等学校实验教学指导委员会、国家级实验教学示范中心联席会以及中国高等教育学会实验室管理工作分会联合举办的第三届全国高等学校自制实验教学仪器设备评选活动中，荣获一等奖。全国近百所高校研制的约 260 台（套）仪器参加了成都新会展中心举办的评选活动，共计评出一等奖二十名。在评选中，我们的斑图测试仪在现场采集到的斑图自主形成过程，即从无序到有序斑图动力学演化过程中的清晰图像，给专家评委留下深刻的印象。

此斑图测试仪是在北京大学实验室与设备管理部教改经费支持下，由物理实验教学中心周路群、贾春燕、冉书能、刘国超四人小组研制。此斑图测试仪因其操作简便，现象丰富，观察直观，且综合性强，并与获 1977 年诺贝尔化学奖的耗散结构理论相结合，向学生们传授非线性动力学科学领域中的相关基本概念，深受学生们的喜爱。其实验讲义已编入了新版 « 近代物理实验 » 教科书，并用于近代物理实验课的教学中。同年，在北京大学科技开发部的支持下，物理实验教学中心与北京杏林睿光公司签订了专利许可转化协议，力图向全国高校范围推广。

图 1：获奖名单 图 2：参评现场

The Measuring Instrument of Nonlinear Thermal Convective Patterns won the first prize at the third session of the self-made teaching experiment instrument selection activities

In November of 2014, the Measuring Instrument of Nonlinear Thermal Convective Patterns NTCPI—Ⅰ won the first prize at the third session of the self-made teaching experiment instrument selection activities from the national wide colleges and universities,jointly organaized by the Chinese Higher Education Association Secretariat,the Guidance Committee of Ministry of Education of Laboratory Construction in higher school, the Guidance Committee of Ministry of Education of college experiment teaching, the Association of National Experimental Teaching Demonstration Center,and the Laboratory Management Branch of Chinese Institute of Higher Education.About 260 sets of instument attended this selection acvitivities from about 100 colleges and universities in Chengdu new exihibition hall. Our intrument impressed experts a lot by the clear images showed on the scene of pattern formations from disorder to order.

The Measuring Instrument of Nonlinear Thermal Convective Patterns was made by a group of four: Zhou Luqun, Jia Chunyan, Ran Shuneng and Liu Guochao in Teaching Center of Physics Experiment, sponsored by reform funds of the Department of laboratory and equipment management in Peking University. The Measuring Instrument is loved deeply by stutends due to the simple operation, rich phenomena, through observation and strong comprehensive, combined with the theory of dissipative structure, which won the 1977 Nobel prize in Chemistry, in order to teach the basic knowledges in nonlinear dynamics of disciplines. The instruction handouts were edited into the textbook of the course, and the instrument was used in the Modern Physics Experiments Course. Under the support of the Ministry of science and technology development, we signed signed a patent license into the agreement with the Beijing Xinglin Real-light Limited Company, trying to spread nation wide.

11 电子显微镜专业实验室 Peking University Electron Microscopy Laboratory

北京大学电子显微镜实验室始创于 1964 年。从创建之初就成为了学校电子显微分析中心。1992 年，被确认为电子光学与电子显微镜国家重点学科专业实验室。在学校“211”“985”等项目的大力支持下，经过近 50 年、几代人的努力，实验室已建设成拥有包括先进的 Tecnai F30 场发射透射电镜、Strata DB235 离子 - 电子双束系统、Quanta 200F 场发射环境扫描电镜等大型电镜 8 台，及完善的电镜制样设备，设备总价值超过 5000 万人民币。

实验室现有包括叶恒强（院士）、俞大鹏（长江特聘教授）在内的教职工 10 名，8 人具有高级职称，6 人具有博士学位。在读博士、硕士研究生 30 余名。以电子显微学及相关领域作为研究方向，涉及到衍射、衬度理论，电子能带结构；分析电子显微学；纳米结构材料及器件；显微结构分析在物理、化学、材料、

电子、地质等学科研究中的应用等。

实验室努力将：建成我国电子显微学的基础研究和专业人才培养基地；高水平显微结构测试、分析和纳米科技研究中心作为奋斗目标。

Electron Microscopy Laboratory, PKU was first established in 1964 and authorized as State Special Laboratory by the ministry of education, P.R.C. in 1992. Under the support of the “985” and “211” projects, a Tecnai F30 TEM，a Strata DB253 FIB and a Quanta 200F ESEM, the most advanced instrument in the world, have been constructed in the laboratory. Now the laboratory is equipped with 8 sets of TEM & SEMs and consummate sample-preparing facilities with over 50 million Yuan. Now there are 10 staffs and over 20 graduate students in the laboratory including an academician of CAS and a national preeminence youth.

Make great efforts to constructed the laboratory to be national base for the research on electron microscopy, professional training and one of the nano-technique research centers. And eventually become a world wide famous laboratory on electron microscopy.

12 高能物理研究中心 Center for High Energy Physics

北京大学高能物理中心由李政道先生担任主任。目前有8位海外资深学者，8位国内特聘兼职研究员，6位青年学者，4位博士后研究人员。研究的领域包括：宇宙学、量子场论、粒子物理唯象学、强子物理等。

With Prof. T. D. Lee as the director, the Center for High Energy Physics at Peking University now has 8 senior fellows from abroad, 8 research associates, 6 junior fellows and 4 postdocs. The research interests include: cosmology, quantum field theory, particle physics phenomenology and hadronic physics.

粲偶素辐射衰变到胶球的格点量子色动力学（Lattice QCD）研究

自然界四种相互作用之一的强相互作用的基本理论公认是量子色动力学（Quantum Chromodynamics, QCD）。与电磁相互作用交换的中间玻色子 -- 光子 -- 不同，QCD 中交换的粒子 -- 胶子之间可以发生直接的相互作用。因此，原则上可以形成一种由胶子构成的奇特强子态，这称为胶球。与其他普通的强子相比较，胶球在许多方面体现出不同的性质，它的理论研究和实验寻找一直都是强子物理方面的热门话题。但是，由于问题的非微扰性质以及胶球与通常强子态的混合，理论上的理解和实验上的直接证据仍然匮乏。从理论上，我们需要一种非微扰的研究方法；从实验上讲，目前在北京正负电子对撞机 / 北京谱仪（BEPCII/BESIII）上正在累计的世界上最大的粲偶素（例如 J/psi）样本为实验上寻找胶球提供了难得的契机。

最近中国格点合作组（China Lattice QCD Collaboration, CLQCD）在此方面研究中取得了重要进展。该合作组系 2005 年由刘川教授等人倡议成立。目前合作组由下列成员构成（以字母排序）：中科院高能所陈莹研究员，北京大学刘川教授，南

开大学刘玉斌教授，中科院理论所马建平研究员，浙江大学张剑波教授以及他们各自的博士后和研究生。该合作组运用格点 QCD 方法—这是一种完全非微扰的理论方法 -- 计算了 J/Psi 辐射衰变到标量胶球和张量胶球的分支比分别为 3.8(9)x10-3 和 1.1(2)x10-2。这是利用格点 QCD 对相关衰变进行直接计算的首个结果（Phys. Rev. Lett. 110, 021601 (2013) 和 Phys. Rev. Lett. 111，091601 (2013)）。当与实验上相关的测量结合，我们的结果说明 f0(1710) 与 f0(1500) 和 f0(1370) 相比更像是标量胶球的候选者。对于张量胶球，文章还建议在多个相关的衰变道进行综合的比较研究。这为实验上寻找胶球提供了颇有价值的理论输入。

A Lattice QCD Study on Glueballs in Charmonium Radiative Decays

Quantum Chromodynamics (QCD) is believed to be the fundamental theory for the strong interaction, one of the four fundamental interactions in Nature. Unlike the mediating particle in Quantum Electrodynamics (QED)--the photons, its counterpart in QCD—the gluons, can have direct interaction among themselves. It is therefore in principle possible to form bound states of gluons which are called glueballs. Glueballs are exotic hadronic states that differ in many ways compared with ordinary hadrons and its search has always been a hot topic in the field. However, due to its non-perturbative nature and also its mixing with the ordinary hadrons, theoretical understanding and the experimental evidence are still scarce. Theoretically, one needs a non-perturbative approach. Experimentally, the world largest charmonium sample, e.g. J/Psi, being collected at BEPCII/BESIII provides a unique opportunity for a comprehensive experimental study of this long-standing problem.

Recently, important progress has been made by the China Lattice QCD Collaboration (CLQCD) which was initiated by Prof. Chuan Liu et al in 2005. The collaboration now consists of Y. Chen (IHEP), C. Liu (PKU), Y.B. Liu (NKU), J.P. Ma (ITP), J.B. Zhang (ZJU) and their postdocs and PhD students. Lattice QCD method (a genuine non-perturbative method) is utilized to study the production of glueballs in charmonium radiative decays. The branching ratios for J/Psi decay to scalar and tensor glueballs is estimated to be 3.8(9)x10-3 and 1.1(2)x10-2 respectively. These are the first results from Lattice QCD (Phys. Rev. Lett. 110, 021601 (2013) and Phys. Rev. Lett. 111，091601 (2013)). These results, when combined with relevant experimental measurements, favors the candidate f0(1710) as the scalar glueball over the other two candidates f0(1500) and f0(1370). As for the tensor glueballs, the results also suggest a comprehensive experimental study in relevant channels. All these have shed some light on the experimental search of glueballs.

13 量子材料科学中心 International Center for Quantum Materials

北京大学量子材料科学中心成立于 2010 年，是一个直属于北京大学的新型教学与科研机构。量子

材料科学中心致力于研究凝聚态物理和量子材料科学的前沿问题，营造国际化的学术创新环境，并力争成为国内领先、国际一流的物理学研究教学平台。

作为一个全新的科技创新平台，量子材料科学中心积极利用政策资源优势，不断改革与完善管理模式和工作方式，通过构建国际前沿的实验设施以及引进国际先进的研究技术，致力于打造一个适合物理学基础研究的开放型学术基地，培养一支具有国际影响力的研究团队，推进以量子科学为基础的高新技术的发展。中心一直着力于人才队伍建设，面向全球招聘教学科研人员，成功引进了一批拥有国际知名度的海内外专家以及众多活跃于国际前沿的年轻学者。截至 2014 年 12 月，中心共有博士生导师 29 人，其中特聘讲席教授 1 人，讲席教授 8 人，教授 3 人，长聘副教授 1 人，预聘制副教授 12 人，预聘制助理教授 4 人。每名教师建有独立的研究小组，实行项目负责人制。成员中 1 人获诺贝尔物理学奖，1 人当选中国科学院院士，6 人入选中组部“千人计划”，2 人当选中国教育部“长江学者特聘教授”， 6 人曾获国家杰出青年科学基金，4 人入选基金委优秀青年基金项目，10 人入选中组部“青年千人计划”，1 人入选中组部“青年拔尖人才支持计划 ”。

量子材料科学中心特别重视年轻学者的培养（包括博士后和研究生培养）。对于博士后人才，中心在世界范围内积极发掘具有潜力的理论和实验人员，目前中心有博士后 15 人，多名博士后在相关领域内取得了重要进展。在研究生人才培养方面，中心现有研究生 100 名，他们均来自国内著名高校，专业成绩名列前茅，对科研有较高的热情。中心给他们提供了一个良好的学习、交流和科研平台。此外，通过夏令营、暑期学校、学术讲座等方式，也为青年学生提供了更多了解凝聚态物理前沿课题的机会。

量子材料科学中心以凝聚态物理和量子材料科学为主要研究领域，目前，中心根据研究方法分为低温及量子输运实验、谱学及高分辨探测实验、自旋及低维磁性实验、凝聚态物理理论、凝聚态物理计算五个研究部分。具体研究方向包括：量子霍尔效应、凝聚态物理中的拓扑效应、关联电子现象、低维电子气中的量子行为、自旋电子学、异质结构物性、介观超导现象、先进扫描探针显微学、中子和光子散射谱学、表面动力学、纳米材料及器件超快动力学实验、超冷原子气、超高压条件下的材料物理、水的特性研究、软物质材料研究等。目前中心共建有（包含正在建设中的 3 个实验室）15 个独立实验室及 1 个纳米微加工公共实验平台。此外，依托中心还建有北京大学崔琦实验室和全校综合性氦气液化回收车间 (北京大学液氦车间)。

量子材料科学中心自成立以来，已承担多项国家重点科研项目，并涌现出一批高质量科研成果，获得了国际学术界的广泛关注与认可。截至 2014 年 12 月，中心共发表 SCI 论文 260 篇，其中多篇发表在 Science，Nature 子刊，Physical Review Letters 等国际顶级学术期刊上。中心教师牵头承担各类科研项目共计 30 余项，科研经费总计约 1.8 亿元人民币，其中包括科技部“973 计划”5 项、国家自然科学基金重大专项 1 项。中心教授还获得了何梁何利奖、亚洲计算材料科学奖、中国科学十大进展、国家自然科学二等奖、陈嘉庚科学奖、教育部“创新团队”等国际国内多项奖励与荣誉。

随着对外合作交流日趋深化，量子材料科学中心已先后与德州大学奥斯丁分校、宾州州立大学、莱斯大学等多所国际著名大学签署了战略合作协议，积极推荐学生参与联合培养、双学位等项目。并通过积极举办具有国际影响力的学术活动和推动顶级学者经常性互访等方式，广泛探索科研合作和人才培养的创新机制，为年轻学者和学生营造一个开放性的、国际化的研究交流环境。

The founding of International Center for Quantum Materials (ICQM) in 2010 marked a major initiative taken by Peking University, aiming to create a platform of world-class excellence for physics research and education. ICQM has since been committed to building interdisciplinary research programs that span a wide spectrum of topics in condensed-matter and materials physics, to be based concretely on an intellectual environment that attracts scholars of the highest-caliber, and on a flexible and supportive infrastructure that promotes creativity, collaboration and exploration at the leading edges.

ICQM is dedicated to bringing in both internationally-renowned scientists and excellent young researchers and enabling them to work together productively in a dynamical culture. Located in Beijing and amid the fast socioeconomical transformation of China, ICQM endeavors to implement new academic systems that include two major components: independent research groups lead by principle investigators and tenure appraisal system. As of December 2014, ICQM has on its faculty 8 Chair Professors, 3 tenured Professors, 1 tenured Associated Professor, 16 tenure-track faculty members. Among the senior researchers are 1 Nobel Laureate, 1 Member of Chinese Academy of Sciences and 7 Fellows of American Physical Society. At full strength, ICQM will have research personnel consisting of 40 permanent members and over 200 Ph.D. students and postdoctoral fellows.

ICQM also provides first-rate research opportunities and solid training to younger scientist, including postdoctoral researchers and graduate students from both domestic and foreign institutions. In the past few years, ICQM has hosted 15 postdocs, several of whom have made important progresses in their research. The graduate students of ICQM are typically graduates from top Chinese universities, with exceptional academic performances. In addition to research, young researchers at ICQM are also profusely exposed to a wide-range of frontier topics research through a rich array of academic activities, such as seminars, lectures and summer schools.

Based on field of expertise, the research at ICQM is organized into 5 divisions, namely

Low temperature and quantum transport experiments;

Spintronics and low-dimensional magnetism experiments;

Spectroscopy and high-resolution detection experiments;

Theoretical condensed matter physics;

Computational physics.

Topics and systems of current interest include quantum transport, strongly-correlated electron systems, low-dimensional quantal systems, topological effects in condensed matter physics, mesoscopic superconducting systems, spintronics, advanced scanning tunneling microscopy, ultra-fast spectroscopy, neutron spectroscopy, ultra-cold atoms, computational simulations for quantum materials, surface dynamics, water behaviors under confinement, soft matters materials, and lots beyond. ICQM has 12 fully operational experimental laboratories with 3 more under construction, supported by a shared nanofab facility and a helium center. The PKU Daniel Chee Tsui laboratory is affiliated to ICQM, which will focus on extremely low temperature physics.

Up to December 2014, ICQM has 260 SCI publications, many of which were published in the most influential scientific journals in the world, such as Science, Nature series journals, Physical Review Letters, etc. The research funding received by ICQM faculty members from Chinese research funding agencies has almost reached 180 million RMB. ICQM members have garnered many national and international awards, such as ACCMS Award, Ho Leung Ho Lee prize, State Natural Science Award.

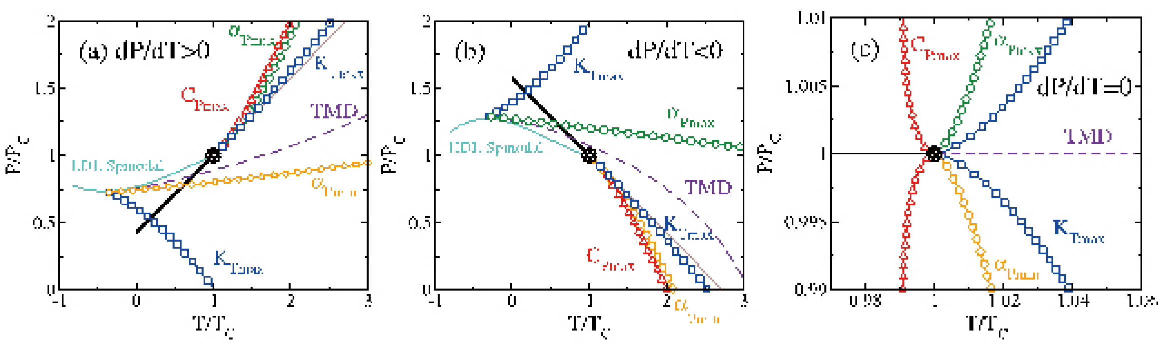
In order to promote academic exchanges and collaborations on the interanational arena, collaboration agreements have been reached between ICQM and world-renowned institutions, such as Rice University, the University of Texas at Austin, Pennsylvania State University. Incoming graduate students may take advantage of the collaboration programs, such as Dual Degree Ph.D. program in Physics. In addition, ICQM has been visited by more than 100 scientists annually through various capacities.

一、从临界到超临界现象

相变与临界现象是统计物理和凝聚态理论的核心内容。物质随外界参量不同而表现出的状态变化以及在临界点会发生的临界现象是相变理论研究的重要课题。在教科书上，以气体－液体相变为例，相图的重要组成部分是两相共存线及二级相变点。在共存线上的任何一点气液两相共存，但其热力学参量不连续。在临界点两相差别消失且响应函数（例如热熔、等温压缩系数等）发散。因此两相共存区的物理图像教科书上已经很清楚了，但是在二级相变点以外更广的相区间即超临界区还没有一个完整的物理图像。

近期研究表明在临界点之外仍然存在超临界现象，即在超临界区存在一条与两相共线对应的热力学响应函数极值线（Widom line）。沿极值线响应函数极值越来越大并在其终点——临界点发散，因此可被广泛应用在具体材料过冷液区临界点的探测中。该团队最新的研究表明在实际的实验具体测量中，对于不同类型的系统，利用超临界现象探测二级相变点需要采用不同的响应函数。例如对两相共存线为正斜率但两相差别特别小的体系，有些响应函数（如热熔）并不是从超临界区趋近临界点，而是从两相共存区趋近。因此实验无法用超临界区的热熔变化来探测此类体系的二级相变点。但是因为其它响应函数（如等温压缩线）在超临界区的行为不变，进而可用来定位临界点。我们的研究给出了不同类型体系实验测量时的具体条件，为实验探测不同类型体系的临界点提供了理论基础，具有重要的实际指导意义。

研究成果发表在《物理评论快报》上（Behavior of the Widom line in critical phenomenon.Phys. Rev. Lett. 112,135701 (2014)）。论文的通讯作者是北京大学量子材料科学中心的徐莉梅研究员。该研究工作得到了国家自然科学基金委，国家科技部等的支持。



图：不同体系临界点附近响应函数极值线。两相共存线为（a）正斜率，（b）负斜率，（c）零斜率。在不同的情况下通过选相应的响应函数总是可以从超临界区来探测到临界点。

Figure: Loci of response function maxima in the vicinity of critical point phenomenon for systems with positively (a), negatively (b) and zero-sloped (c) coexistence line. The critical point can be traced as the terminal point of response function maxima from the supercritical region in all circumstances by choosing proper response functions.

I. From critical to supercritical phenomenon

Substance undergoes phase transitions when external fields vary. It has been know that thermodynamic properties are discontinuous along the two-phase coexistence line while they become continuous at the critical point where the difference between two phases disappear. However, the behaviors of different response functions beyond the critical point in the supercritical region remain unclear even for the simple gas-liquid phase transition.

Recent studies by Xu et al showed that there exists supercritical phenomenon beyond the critical point. That is, the response functions have maxima. The loci of response functions maxiam in the vicinity of the critical point is termed as the Widom line along which the magnitude of response function maxima become larger till it diverges as the critical point is approached from the supercritical region. This phenomenon has been employed to experimentally detect the critical point as the terminal point of response maxima from supercritical region in practical systems. The study also revealed that for different systems (e.g., the slope of the system is positive, negative, or almost horizontal), different response function should be employed in tracing the critical point. For instance, when the slope of the coexistence line is almost zero, the line of specific heat maxima does not follow the Widom line but instead follows the coexistence line. This has relevance for the detection of second critical points for systems exhibiting a nearly horizontal coexistence line. The theoretical predictions by Xu et al are confirmed by computer simulations and provide theoretical basis for the detection of critical point under different circumstances.

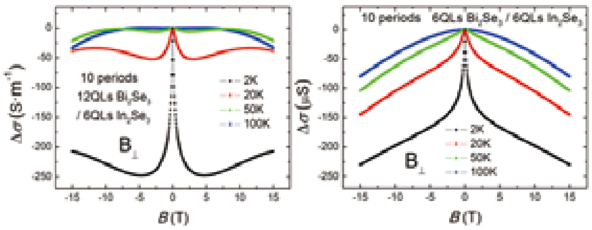
This work was published in the journal of Physical Review Letter (Phys. Rev. Lett. 108, 128101 (2012). Prof. Limei Xu at the International Center for Quantum Materials directed this research. This work was partially supported by the NSF of China and the MOST of China.

二、拓扑绝缘体超晶格的量子输运和调控

拓扑绝缘体体内是有能隙的绝缘体，而表面是无能隙的自旋轨道耦合的金属态。作为一种新的量子材料，拓扑绝缘体已成为当前凝聚态物理最重要的研究领域之一。超晶格是指在纳米尺度可人工调制周期的晶体结构。最新的理论研究表明，拓扑绝缘体的特殊表面态是 Weyl 电子的二维体现，而拓扑绝缘体 / 普通绝缘体形成的超晶格可以构成理论预言的三维 Weyl 半金属，从而观测到真正的三维表面态。更为重要的是，拓扑绝缘体超晶格结构，有望实现对拓扑材料物性的人工调制。因此拓扑绝缘体超晶格的研究对于发现新的量子现象以及探索新的量子材料都具有重要科学意义。然而，拓扑绝缘体 / 普通绝缘体超晶格的电输运实验研究及可调控特性一直未见报道。

最近，王健研究组与谢心澄教授等人合作首次对于拓扑绝缘体 / 普通绝缘体（Bi2Se3/In2Se3）超晶格的量子输运特性展开系统研究。在低温强磁场下对不同拓扑绝缘体层厚的 Bi2Se3/In2Se3 超晶格的电输运测量发现：改变其中拓扑绝缘体层 Bi2Se3 的厚度会导致体系的量子输运维度从三维转变为二维。该结果证实了人工调控拓扑材料物性的可行性，是拓扑绝缘体超晶格量子输运特性的

首次报道。这一工作不仅为新量子态的探索，也为研发人工调制的拓扑材料及其在磁电、热电和自旋电子学等方面的潜在应用奠定了基础。相关工作



以“Crossover from 3D to 2D Quantum Transport in Bi2Se3/In2Se3 Superlattices”为题，发表在《纳米快报》(Nano Letters 14, 5244 (2014)) 上。

图： (Bi2Se3)12/(In2Se3)6 和 (Bi2Se3)6/(In2Se3)6 超晶格的量子输运特性

Figure: Transport properties of (Bi2Se3)12/(In2Se3)6 SLs and (Bi2Se3)6/(In2Se3)6 SLs

II. Quantum transport and modulation in topological insulator/normal insulator superlattices

Prof. Jian Wang’s group, in collaboration with Prof. Xin-Cheng Xie, Prof. Maohai Xie and Prof. Yong Wang et al., firstly and systematically studied the transport property of the artificial TI/NI SL systems. They investigated the quantum transport of SL heterostructure consisted of different thickness of TI layers，and found that tuning the thickness of TI Bi2Se3 layers may completely change the transport dimensionality from 3D to 2D in Bi2Se3/In2Se3 SLs. The discovery demonstrated the feasibility of modulation of topological material property by using TI/NI SLs. This work may stimulate the research on exploring exotic quantum state and potential magneto-conductance, thermoelectric and spintronics applications in TI/NI SLs. The results were published in Nano Letters (Nano Letters 14, 5244 (2014)) with a title of “Crossover from 3D to 2D Quantum Transport in Bi2Se3/In2Se3 Superlattices”.

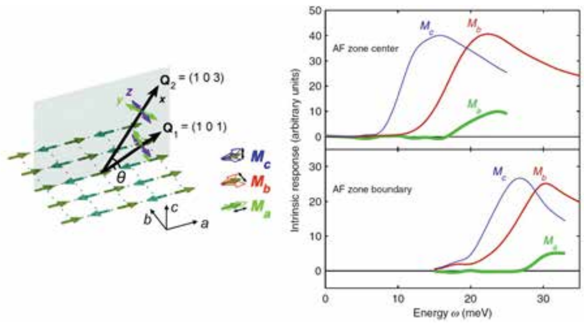
三、铁基超导体中巡游电子对磁性的贡献

铁基超导体发现于 2008 年，是继铜基超导体之后发现的又一大类高温超导材料，这为高温超导微观理论的建立带来了新的机遇和挑战。在相图中，铁基超导体中的超导态常常出现在反铁磁态的边缘，因此超导与磁性一直被认为可能有很大的关系。然而在超导研究领域对这种磁性的微观起源一直存在争议：一种观点认为反铁磁性来源于局域电子的自旋磁矩，另一种观点认为磁性起源于巡游电子的集体行为。虽然有很多实验试图去验证这两种观点，但却没有一个确凿的直接证据能肯定其中任何一个说法。

这两种图像的关键区别之一是材料在磁有序态下具有不同的自旋激发谱。在局域电子图像中，电子磁矩有着确定的大小，因此自旋激发只能是围绕着排布方向的进动，也就是“横模激发”；而在巡游电子图像中，磁矩的幅值依赖于参与贡献磁矩的巡游电子数量，因此自旋激发会多出一个幅值振动的模式，也就是“纵模激发”。

在本项工作中，李源研究组与中科院物理所以及法国劳厄 - 朗之万实验室的合作者利用自旋极化的非弹性中子散射，对铁基超导母体材料 BaFe2As2 的自旋激发谱进行了研究。该实验方法

能够直接探测电子自旋的振动方向。使用目前最先进的谱仪和大尺寸的单晶样品，他们获得了非常高的数据精度，证明了纵模自旋激发的存在。这项发现为铁基超导体中反铁磁性的巡游电子起源找到了确凿的证据，这更加确定了巡游电子在磁性和超导之间的重要纽带关系。实验结果发表在顶级物理期刊《物理评论 X》上（Longitudinal spin excitations and magnetic anisotropy in antiferromagnetically ordered BaFe2As2, Phys. Rev. X 3, 041036 (2013)），文章的第一作者王冲同学是北京大学量子材料科学中心的 12 级博士研究生。该研究工作得到了中国国家基础研究项目和中国国家自然科学基金的支持。



图：左图为横模（M_b, M_c）与纵模（M_a）自旋激发的示意图，以及中子散射过程中的动量改变方向与自旋排布的相对关系。右图为实验结果，表明在动量空间的不同位置都能探测到纵模自旋激发的信号。

Figure: Left panel illustrates transverse (M_b, M_c) and longitudinal (M_a) spin excitations, along with momentum transfer direction in the scattering process relative to the antiferromagnetic spin arrangement. Right panel shows the experimental results, which demonstrate the presence of longitudinal spin excitations at different locations in the momentum space.

III. Direct evidence for an itinerant-electron origin of magnetism in iron pnictide superconductors

Iron pnictides, a class of high-temperature superconductors discovered only in 2008, have presented many fundamental puzzles for physicists working on superconductors. One of the puzzles is the proximity of an antiferromagnetic phase to the superconducting phase in these materials, raising the tantalizing possibility of a fundamental connection between magnetism and superconductivity. What is the microscopic origin of the magnetism, then? Existing experiments point to two possibilities: The magnetism either arises from spin moments of electrons localized on the iron nuclei, or results from the collective ordering of spins of itinerant electrons. However, no “smoking gun” evidence has been found for either of these possibilities.

The above two scenarios leave fundamentally different signatures in how the microscopic magnetic moments in the antiferromagnetic state vibrate when excited. In the local-moment picture, the moments have a fixed size, so the vibrations are dominated by precessions around the ordering direction. In the itinerant-electron picture, the sizes of the moments themselves can be modulated, giving rise to additional “longitudinal spin excitations.”

In this work, Prof. Yuan Li’s group, in collaboration with researchers at the IOP/CAS and at the ILL, France, investigated the spin excitations in BaFe2As2, a “parent” compound of iron pnictide superconductors, using spin-polarized inelastic neutron scattering. This technique can determine the direction of the electron spin excitations. Using state-of-the-art instrument together with a very large single-crystal sample, they have achieved unprecedented precision in the spin excitation signal, which allowed them to uncover an unequivocal signature of longitudinal spin excitations in the experimental spectrum. This result can be regarded as the first smoking-gun evidence for a sizable contribution of itinerant electrons to the antiferromagnetism, and it puts the plausible connection between magnetism and superconductivity on a firmer footing. The work was published in Phys. Rev. X 3, 041036 (2013), "Longitudinal spin excitations and magnetic anisotropy in antiferromagnetically ordered BaFe2As2" . The first author of the paper is Chong Wang, a Ph.D. student at the ICQM, Peking University. This work was supported by MOST and NSFC.

14 北京大学科维理天文与天体物理研究所 The Kavli Institute for Astronomy and Astrophysics (KIAA)

科维理天文与天体物理研究所是北京大学和美国 Kavli 基金会合作于 2006 年 6 月成立的，并于 2007 年开始正式运行。研究所致力于建设一个国际一流的天文与天体物理研究中心，在活跃的学术氛围下，开展前沿天体物理领域的基础科学研究。工作语言为英语。研究所积极参加理论和观测天体物理研究项目，开发和利用观测设备，培养本科生、研究生和博士后。定期举办专题研讨会和学术会议，并开展一系列旨在推动与国内外天文界合作与交流的学术活动。研究所与其它 Kavli 研究所以及世界上很多大学和研究机构建立了各种交流与访问计划。

研究所的主要研究领域包括：1) 观测宇宙学，星系的形成与演化；2) 恒星形成，恒星与行星系统 ; 3) 引力物理和高能现象；4) 计算天体物理。

研究所现任所长何子山，副所长吴学兵，协调人陈建生。由国际科学顾问委员会 (SAC) 在学术活动、重大计划、研究方向和教师聘用等方面提供指导。研究所与天文学系合作密切，人员共聘，资源共享，联合开展科学研究和人才培养。经与天文学系和其它天文单位联合聘用，研究所目前有 24 位教师，15 个博士后和许多访问学者。

更多信息，请访问科维理天文与天体物理研究所网页：http://kiaa.pku.edu.cn/.

The Kavli Institute for Astronomy and Astrophysics (KIAA) is jointly supported by Peking University and an endowment made possible by a generous gift from the Kavli Foundation, USA. KIAA was established in June, 2006 and started operation in 2007. KIAA's mission is to establish an international center of excellence in astronomy and astrophysics that promotes the development of basic astrophysical research. Its primary goal is to foster frontier research in a vibrant intellectual environment. With English as its working language, KIAA is engaged in theoretical and observational initiatives, development and utilization of astronomical facilities, and training of undergraduate and graduate students and postdoctoral fellows. KIAA regularly sponsors thematic workshops, conferences, and a range of other academic activities to facilitate scientific exchange with the domestic and international astronomy community. It is establishing exchange and visiting programs with other

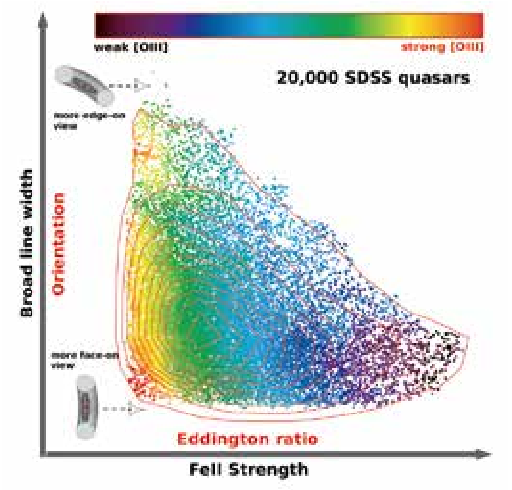
Kavli institutes and a network of universities and astronomy centers worldwide.
The program of KIAA focuses on four major areas of astrophysics: 1) observational cosmology, galaxy formation and evolution; 2) star formation, stellar and planetary systems; 3) gravitational physics and high-energy phenomena; and 4) computational astrophysics.
The Institute is under the leadership of its Director Luis C. Ho, Associate Director X.-B. Wu, and coordinator J. S. Chen. An international Science Advisory Committee provides guidance concerning proposed academic activities, assistance on major projects to set research directions, and review of new faculty appointments. KIAA works closely with the Department of Astronomy, via coordination of research activities, sharing of research facilities and resources, and training and supervising of students. Together with several joint appointments with the Department of Astronomy and other institutions, KIAA currently has 24 professors, approximately 15 postdoctoral fellows, and a number of visiting scholars.
For more information, please refer to KIAA homepage: http://kiaa.pku.edu.cn/.

一、类星体主序的研究

类星体是遥远星系中央的正在吸积的超大质量黑洞，其质量可以达到太阳质量的几百万到几十亿倍。由于黑洞吸积释放的大量辐射能量，黑洞附近的气体被电离并产生各种元素的谱线。类星体现象学即通过研究吸积中的超大质量黑洞的辐射能谱以及发射谱线的流强和动力学性质来揭示黑洞吸积的物理本质。

在过去几十年的类星体研究中天文学家已经发现类星体的多波段光谱性质呈现出很强的多样性，体现了不同类星体系统之间的个体差异。另一方面，这类多样性呈现出很强的规律性，即大多数的类星体观测属性都沿着一条由光学波段的铁发射线的强度定义的主序而有规律的变化（Boroson & Green 1992, ApJS, 80, 109）。这一主序被称为类星体的第一本征矢量，长期以来是研究类星体现象学的一个最重要的工具。但是决定第一本征矢量的物理原因一直没有得到很好的解决：天文学家猜测其背后的主导物理是黑洞吸积的效率，天文上称为爱丁顿比的一个物理量。理解类星体主序对于理解黑洞吸积有及其重要的意义。

利用斯隆数字巡天的海量类星体数据，沈悦和何子山重新深入研究了类星体第一本征矢量这一问题。大样本的统计观测数据提供了新的途径来研究类星体主序的本质。沈悦和何子山的研究利用了大样本巡天时代的新的统计方法对类星体主序的应用。通过研究类星体的成团性质随主序的变化，沈和侯首次严格的确认了爱丁顿比是驱动类星体这一主序的根本原因。此外，通过对类星体光谱宽发射线的动力学研究，沈和侯指出类星体的宽线区气体来自一个扁平的盘状分布，因此宽发射线的宽度受视线方向和盘主轴方向的夹角影响。这一额外的发现对于利用宽发射线的动力学估计黑洞质量有重要的意义，并提供了一条改进类星体质量估计的途径。基于这些观测结果，沈和侯提出了一个简单的统一模型，只需要两个物理参数，爱丁顿比和方向性，来解释类星体的多样性。这一工作解决了一个二十年来困扰类星体研究的难题，并为建立更完善的类星体吸积理论提供了观测的依据。这一工作发表在 2014 年 9 月 11 日的《自然》杂志上。



约 2 万个高光度的斯隆数字巡天类星体在二维线宽和铁线强度平面上的分布。色调对应氧窄线的强度。水平方向的趋势即所谓的类星体主序，由类星体黑洞吸积的效率决定；而垂直方向上的线宽的分布则主要由观测者的视线方向与类星体内区的夹角决定。

The distribution of about 20,000 luminous Sloan Digital Sky Survey quasars in the two-dimensional space of broad line width versus FeII strength, color-coded by the strength of the narrow [OIII] line emission. The strong horizontal trend is the main sequence of quasars driven by the efficiency of the black hole accretion, while the vertical spread of broad line width is largely due to our viewing angle to the inner region of the quasar.

I. Research on the quasar main sequence

Quasars are accreting supermassive black holes (SMBHs) at the center of distant galaxies, with a black hole mass several million to several billion times the mass of the Sun. Due to the intensive radiation from BH accretion, gas near the hole will be ionized and produce copious emission lines in different elements. Quasar phenomenology is a subject to reveal the physical nature of BH accretion by studying the observed properties of the emission spectrum as well as the strengths and kinematic properties of the emission lines.

During the past several decades, astronomers have known that the multi-wavelength properties of quasar spectra display a strong diversity, reflecting the differences among different systems. On the other hand, this diversity appears to be organized, i.e., most of the quasar properties seem to vary along a main sequence defined by the strength of the optical iron emission (Boroson & Green 1992, ApJS, 80, 109). This main sequence is called Eigenvector 1 (EV1), and has been one of the most important tools to study quasars. But it remains unclear what is the physical driver of EV1: astronomers speculate the main physical driver is the efficiency of BH accretion, a quantity called the Eddington ratio. Understanding the nature of the quasar main sequence is critical to understanding BH accretion.

Using the massive data set on quasars from the Sloan Digital Sky Survey, Yue Shen and Luis Ho revisited this important EV1 problem. Large statistical samples of observational data provide a new path to understand the nature of the quasar main sequence. Shen and Ho’s work took advantage of several novel statistical tools that were made possible in the large-scale survey era. By studying the change in the quasar clustering properties along the EV1, Shen and Ho for the first time confirmed that Eddington ratio is the main driver of EV1. In addition, by studying the kinematics of the broad emission lines in quasar spectra, Shen and Ho pointed out that the broad-line region gas is distributed in a flattened disk geometry, and the observed line width is affected by the angle between the line-of-sight and the normal of the disk. This additional discovery has important implications for estimating quasar BH mass using the kinematics of the broad emission lines, and offers a new way to improve quasar BH mass estimation. Based on these observational results, Shen and Ho proposed a simple unification scheme, in which only two physical parameters, the Eddington ratio and orientation, are required to explain most of the diversity in quasar properties. This work solves a two-decade puzzle in quasar research, and provides a critical observational basis for establishing more advanced quasar accretion theory. This work was published in the Sep 11, 2014 issue of Nature (Shen & Ho, 2014, Nature, 513, 210).

二、哈勃望远镜对中等年龄星团的观测颠覆演化理论传统认知

星团是包含成千上万颗恒星的恒星系统，人们相信它们的演化轨迹已经被研究透彻了，然而，好景不长，对哈勃太空望远镜观测结果的最新研究可能打击了科学家的这一自信。

直到数十年以前，大质量星团都被认为是“单星族”的：所有的恒星都大约同时从同一片分子云里坍塌形成，因此要理解这些恒星系统的集体演化并不困难。然而，在那以后，这一认识被极大地改变了，大质量星团，尤其是它们当中特别年老的球状星团，被认为不再是由单一星族构成，而是由年龄范围分布广泛的不同星族构成。来自北京大学科维理天文与天体物理研究所和中国科学院国家天文台的研究者们，利用哈勃太空望远镜对银河系周边大麦哲伦云星系中的星团 NGC1651 进行了观测，他们的研究结果强烈表明，中等年龄的大质量星团可能依旧是由单星族构成的。

恒星一生的大部分时间，都在核心产生氢核聚变（氢原子聚合成氦原子）反应，以维持自身发光发热，这样的恒星称为“主序星”，它们分布在“赫罗图”（恒星颜色和亮度分布的二维图）的主序带上。当恒星核心的氢原子全部燃烧完时，核心周围壳层的氢元素就开始燃烧，此时恒星就进入“转折区域”，演化到“亚巨星”带上，单星族恒星分布的亚巨星带十分狭窄。近十几年以来，人们对年龄在 10 亿到 30 亿年的大质量星团（质量在 50000 个太阳质量以上）观测发现，它们的恒星在赫罗图上呈现出一个展宽的转折区域，这一现象长期被解释为恒星的年龄存在 3 亿年左右的弥散（它们不是同时形成的）。

项目的主要成员之一，北京大学的博士研究生李程远认为“这一解释十分让人困惑，因为年轻的星团会在最初的数千万年时间内迅速消耗掉可供恒星形成的所有气体。”

研究成员对星团 NGC1651 的分析发现，尽管和其它星团一样，它的主序转折区域看起来貌似存在很大的年龄弥散（约 4.5 亿年），它的亚巨星支却十分狭窄，这标志着它根本没有任何年龄弥散：如果星团是由年龄连续分布的星族组成，这些恒星应该同时分布在一个展宽的亚巨星支上，令人惊讶的是，分析这些亚巨星分支的宽度表明，它们的年龄弥散最多不会超过 8000 万年。

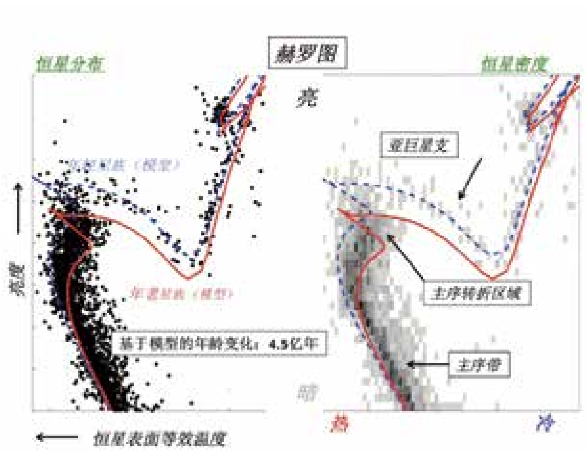
“NGC1651 可能是迄今为止所有星团中存在单星族的最好样本”来自科维理研究所的理查德 . 德 . 何锐思教授说，“我们已经发现还有许多其它星团也存在类似的特征。”

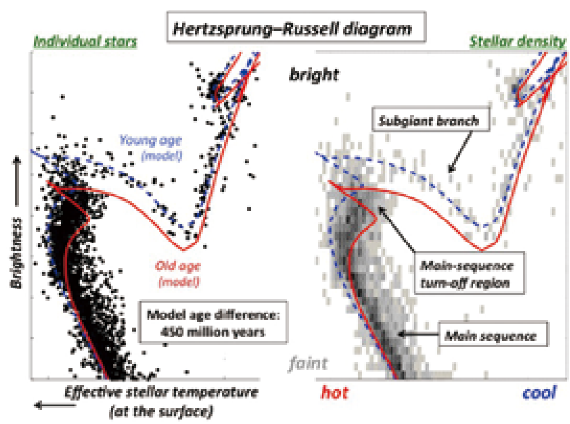
研究团队认为，这一令人惊讶的恒星分布最有可能的解释是恒星在围绕自身主轴以不同的速率自转，来自国家天文台的首席科学家邓李才教授评论说：“这一发现将终结近十年来科学家们关于这一话题的争论，正如同文章的同行审稿人评价的那样，这一结果‘可靠且令人鼓舞’。”

这一工作以文章快报的形式发表在《自然》杂志上，原文链接：2014/12/18

Li C., de Grijs R., Deng L., 2014, Nature, 516, 367

NGC1651





II. Hubble Space Telescope observations of two billion-year-old star cluster suggest evolutionary paradigm reversal

As compact aggregates containing up to millions of stars each, the evolution of star clusters was commonly considered well-understood. However, first impressions rarely last. New analysis may have finally settled a debate that has long baffled scientists.

Until about a decade ago, such massive star clusters were thought to have formed all of their member stars at approximately the same time from the same gas cloud, so that their ongoing evolution could be understood rather easily. In the mean time, this concept has changed dramatically. Massive star clusters, and in particular the old, so-called 'globular' clusters that formed at the time of galaxy formation, are no longer considered 'simple' single-generation stellar populations. Instead, they are usually thought to contain stars that formed over extended periods. However, based on Hubble Space Telescope images of the star cluster NGC 1651 in the Large Magellanic

Cloud, a satellite galaxy of the Milky Way, researchers at the Kavli Institute for Astronomy and Astrophysics (KIAA) at Peking University and the National Astronomical Observatories (Chinese Academy of Sciences) in Beijing found that middle-aged massive star clusters may be ‘simple’ after all.

Stars spend most of their lifetimes converting hydrogen into helium in their cores on the so-called ‘main sequence’ in the diagnostic Hertzsprung–Russell diagram, which relates the stellar surface temperatures to their brightnesses. When the core hydrogen supply has been exhausted, stars leave the main sequence and evolve onto the ‘subgiant branch.’ For a single-age population of stars, one expects to see a narrow, well-defined sequence in the diagnostic diagram. However, observations of clusters with masses greater than about 50,000 times the mass of our Sun, and ages between approximately one and three billion years, often find extended main-sequence turn-off regions. These are commonly interpreted as evidence of age spreads of more than 300 million years.

“This has long been a surprising inference, because young clusters are thought to quickly lose any remaining star-forming gas during the first 10 million years of their lifetimes,” said Chengyuan Li, PhD student at Peking University and lead author of the new study.

The researchers found that although the cluster’s extended main-sequence turn-off region is well-described by adoption of an age dispersion of approximately 450 million years, the cluster’s very tight subgiant branch places the strongest constraints yet on the maximum likely age range in the cluster. To their surprise, the team found that the narrow width of the cluster’s subgiant branch can only be reconciled with a spread in stellar ages of less than 80 million years.

“We concluded that NGC 1651 is the best example found to date of a truly single-age stellar population,” explained Richard de Grijs, faculty member at the KIAA and Chengyuan Li’s PhD supervisor. “We have now identified a handful of other clusters that appear to show similar features.”

The team’s most plausible explanation of this surprising paradigm reversal is the presence of a population of stars in the cluster that rotate around their axes at different rates. Licai Deng, principal scientist at the National Astronomical Observatories, commented that “these latest results resolve nearly a decade of debate among scientists; as such, the results were deemed ‘solid and welcome’ by the peer-reviewers.”

The resulting article was published in the journal Nature on 18 December 2014:

Li C., de Grijs R., Deng L., 2014, Nature, 516, 367

学生活动
Students

2013 年 10 月 19 日，北京大学物理学科建立一百周年纪念活动成功举办。物理学院 12 级本科生在北大物理百年庆典上演唱原创歌曲《百年物理》。物理学院团委新媒体中心拍摄北大物理百年庆典学生微电影《李群的变换》。

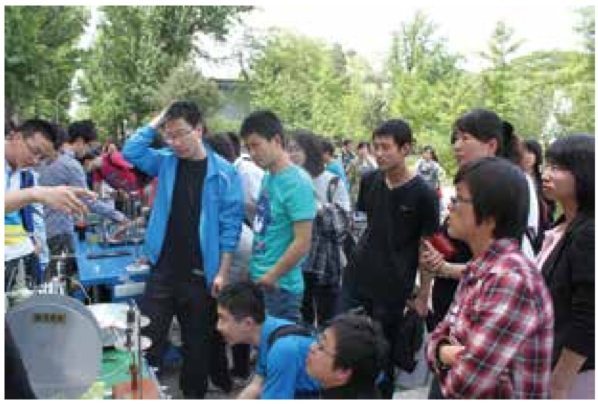
On October 19 2013, the school held the celebration conference to commemorate the 100th anniversary of physics education at Peking University. The ’12 undergraduate class performed the original chorus “Centennial Physics” at the conference. The school’s New Media Center students also filmed the micro film “The Transformation of Qun Li.”

北京大学 2013 年“百年物理·人”物理文化季开幕式暨“物理这一百年”主题对话活动邀请到著名物理教育学家、物理学院教授赵凯华，北京大学 2011 年“十佳教师”郭卫应邀作为对话嘉宾出席活动。2014 年“百年物理·人”物理文化节开幕式暨“俯仰天下究物理”主题论坛邀请到中国科学院院士欧阳颀、龚旗煌与青年学子共话成长求学的经历。

The Centennial Physics Cultural Season 2013 invited Prof. Kaihua Zhao, renowned physics educationist and Prof. Wei Guo, the “PKU best teacher of the year 2011” to exchange with PKU students. The Centennial Physics Cultural Season 2014 invited the academicians Profs. Qihuang Gong and Qi Ouyang to share their school and career development experiences.

2013 年 3 月，别开生面的“物理大观园”演示实验活动在三角地顺利举行。本次活动由物理学院团委主办，物理学院青年志愿者协会组织承办，通过一系列奇幻美妙的演示实验，给更多的同学们展示了一个精彩绝伦的物理世界。

In March 2013, the “physics showplace” experiment demonstrations activity was held at PKU campus. The activity was aimed to present to students a wonderful physics world through miraculous experiment demonstrations.



2013 年 4 月，由物理学院主办的首届全国大学生显微图片大赛优秀作品展览在生科金光楼大厅举行，全国共十所高校参与此次赛事。2014 年 9 月，物理学院图书接力活动成功举办，学院青协、学生会在毕业季回收老生用书，并在秋季学期开学向新生免费发放。

In April 2013, the 1st National Students Microscopic Photo Filming Contest was held by our school. Students from over 10 universities from China attended this contest. In September 2014, the school held the Books Relay activity, which calls on students to reclaim books from close-to-graduation students and give them out to freshmen students.

2013 年 8 月，北京大学学生军训开训仪式举行。于 2013 年刚组建的物理学院游泳队，在 2013 年、2014 年连续两年获得北大游泳比赛总分第一名。2014 年 10 月，北大“新生杯”篮球赛成功举办，物理学院天文系大一班级勇夺桂冠。

The university held the student military trainings in every August. The school's swimming team which was built in 2013 won the 1st place from two consecutive years. In October 2014, the astronomy freshmen class ranked 1st in the PKU “Freshmen Cup” Basketball Competition.

2013 年 7 月，物理学院实践团参观国家海洋局南海分局并于海监 169 船旁合影。同月，实践团在欧阳里程校友的带领下参观广东省气象局。

In July 2013, the school's summer vacation social practice team visited the National Bureau of Oceanography and took a photo with China Coast Guard 169. The team also visited the Meteorological Bureau of Guangdong Province.

第五届中国大学生物理学术竞赛于 2014 年 8 月在华中科技大学举行。比赛中，北大代表队秉承优良传统，锐意进取，奋勇争先，成功晋级决赛，最终获得第五届中国大学生物理学术竞赛一等奖；参赛队员 2013 级本科生李泽阳获“最佳选手”单项奖。第十一、二届“北京大学钟盛标物理教育基金”颁奖典礼成功举办，基金设立人钟赐贤先生及夫人夏晓峦女士对物理学院钟盛标论坛获奖师生进行表彰。

The 5^{th} National College Student Physics Academic Competition was held in 2014. The school's representative team won the 1^{st} place in the competition. Student Zeyang Li from the '13 undergraduate class won the “best competitor” medal. The 11^{th} and 12^{th} awards ceremonies of Choong Shin-Piaw's Physics Educational Fund at PKU were held in May of 2013 and 2014.

物理学院 2013 级新生开学典礼在英杰交流中心阳光大厅成功举行。物理学院 1958 级校友赵元果先生作为校友代表参加仪式。物理学院 2014 年毕业典礼在北京大学英杰交流中心阳光大厅举行。物理学院党政领导班子成员、教师代表、校友代表及 2014 届全体毕业生和家长共 625 人参加了此次典礼。

In 2013, the school's opening ceremony took place at the Yingjie Exchange Center at PKU, during which the alumni representative Yuanguo Zhao from the '58 class delivered a welcoming speech. In 2014, a total of 625 representatives that consist of the school's managing team, representative professors, alumni, the 2014 graduation class and their parents took part in the ceremony.

校友与基金
Alumni and Funds

1913 年，北京大学正式设立“物理学门”，成为北京大学物理学教育的开端。2013 年 10 月 19 日，北京大学物理学科建立 100 周年庆祝大会在邱德拔体育馆隆重召开，纪念北大物理一个世纪以来走过的风雨兼程、求真报国的光荣岁月。

On October 19 2013, the school held the grand conference to celebrate the 100th anniversary of the Physics Education at PKU.

玉盘高挂，华灯初上。19 日晚在北京大学百周年纪念讲堂观众厅隆重举行物理学科建立 100 周年庆典晚会，邀请中国东方演艺集团（东方歌舞团）主演，物理系的千余名系友、老师和学生齐聚一堂，共同庆祝北京大学物理学科百年华诞。

The school also launched the evening program that invited the Oriental Song and Dance Company to deliver celebration performances.

10 月 18 日下午，北京大学物理学院校友捐赠仪式在北京大学英杰交流中心新闻发布厅举行。物理学院 77 级校友夏廷康等二十多位校友代表出席了捐赠仪式。

On October 18, the school’s Alumni Donation Ceremony was held at the Yingjie Exchange Center at PKU. More than 20 alumni representatives attended the ceremony.

2013 年 9 月，物理学院谢心澄院长和董晓华副书记赴上海参加上海校友会组织的迎接北大物理百年系列活动之上海物理学科校友大会。

In September 2013, Dean Xincheng Xie and Party Deputy Secretary Xiaohua Dong went to Shanghai to attend the PKU Physics Alumni Gathering.

2013 年 11 月，董晓华副书记赴深圳参加北大校友会第八届会员代表大会。

In November 2013, Party Deputy Secretary Xiaohua Dong went to Shenzhen to attend the 8th Representative Congress of PKU Alumni.

2014 年 1 月，物理学院于中关新园“1898”咖啡厅举办新春校友交流会暨毕业生求职交流会，邀请一批在工业、金融和科研领域工作的校友回校，与即将面临就业的毕业生同学进行交流。

In January 2014, the school held the Spring Festival Party for PKU physics alumni at the 1898 Coffee House. Alumni from various fields were invited to exchange with school students close to graduation.

2014 年 5 月 3 日，物理学院近百位校友聚首燕园，共庆北京大学建校 116 周年华诞。物理学院在邱德拔体育馆北广场设置全天接待站，为返校校友提供咨讯和服务。

On May 3 2014, over 100 alumni returned to campus celebrate the 116^{th} anniversary of Peking University. The school set up the reception station to welcome and serve the school alumni.

5 月，“校友开讲 ”第二期暨第 54 期“萃英研究生学术沙龙”在物理楼中 312 报告厅举行。物理系 85 级校友朱大斌学长受邀回到学院，与在场学生分享了自己丰富精彩的人生经历。

In May 2014, the ’85 class alumni Dabin Zhu was invited back to share with students his achievements and reflections on career development.


同月，北京大学校友会、物理学院校友办公室和物理学院青年志愿者协会在中关新园咖啡厅里联合采访了物理学院院友、2013 年度“美国总统青年科技奖”获得者吴军桥教授，在采访期间，吴教授耐心地解答了相关问题，并给出了自己精彩的答案。

In May, we interviewed Dr. Junqiao Wu, the school alumni representative and the winner of the 2013 “Presidential Early Career Awards for Scientists and Engineers.”

7 月，北大物理 80 级校友举办毕业三十周年聚会，其间安排校友大会、捐赠仪式、分会场研讨会、校园参观、体育活动等项目，校友们重聚燕园，分享经历，十分欢欣。

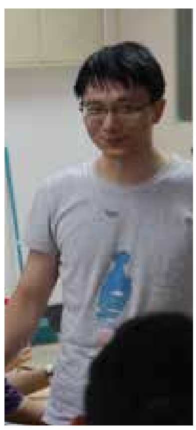
In July, the ’80 physics class held the gathering party to celebrate the 30th anniversary of graduation and the establishment ceremony of the ’80 physics class fund.


9 月，先后举办 04 级本科生、研究生入学十周年返校活动暨“十年”系列迎新座谈会。

In September, the ’04 undergraduate and graduate physics classes were invited back to talk to the ’14 physics freshmen.

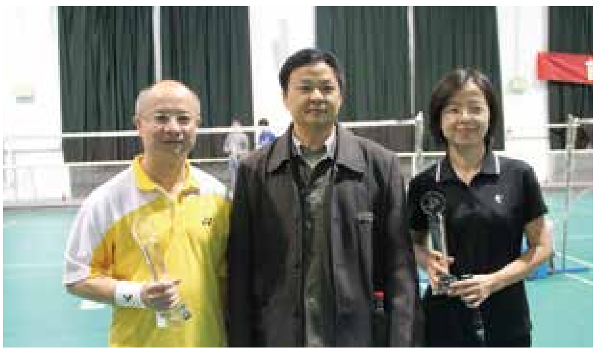






2014 年 11-12 月，物理学院首届校友羽毛球赛在北京大学五四体育馆成功举办。本届赛事由物理学院主办，物理学院校友会、研究生会、学生羽毛球队联合承办，旨在以球会友，激发校友运动激情，拓展校友联络平台，加强校友归属感和凝聚力。

In September and December 2014, the school held the 1st session of Alumni Badminton Contest at PKU. The purpose of the contest was to promote alumni closeness and inspire passion for body exercises.



2013 年度，学院校友基金收到捐赠约￥2,299,233.46，发放奖教金、奖助学金及其他支出总计约￥473,620.86，申请配比基金约￥1,048,366.94。2014 年度收到捐赠约￥2,668,550.08，发放奖教金、奖助学金及其他支出总计约￥1,931,158.14，申请配比基金约￥1,425,435.71。截止 2014 年底，学院校友基金项目余额总计约￥13,300,000.00。

In 2013, the school alumni funds received ￥2,299,233.46 in donation, spent ￥473,620.86 in awarding scholarship, supporting student activities and student aid, applied for and were granted ￥1,048,366.94 in matching funds. In 2014, we received ￥2,668,550.08 in donation, spent ￥1,931,158.14, and received ￥1,425,435.71 in mating funds. Until the end of 2014, the school had accumulated about ￥13,300,000.00 in alumni funds.

校友基金项目：
Alumni Funds:

校友捐赠基金 The Alumni Funds	创立时间 Time of Establishment
叶企孙实验物理基金 Qisun Ye Experimental Physics Fund	1987
冯溪乔奖学金 Shechao Charles Feng Scholarship	1996
谢义炳基金 Xie Yibing Fund	1996
77 物理班级基金 ’77 Physics Class Fund	2002
钟盛标物理教育基金 Paul Shin-Piaw Choong Educational Fund for Physics	2002
80 物理兰怡女子助学金 ’80 Ellen Yi Lan Woman Physicist Scholarship	2005
86 物理班级基金 ’86 Physics Class Fund	2005
88 物理班级基金 ’88 Physics Class Fund	2006
克诚奖学金 Kecheng Scholarship	2006
德康霓克奖学金 (校级项目) Taconic Scholarship (University level)	2007
帝光奖学金 Di Guang Scholarship	2007
陈互雄物理教育基金 Huxiong Chen Educational Fund for Physics	2008
冯溪乔特别奖学金 Shechao Charles Feng Special Scholarship	2008
胡宁奖学金 Ning Hu Scholarship	2008
赵凯华物理教育基金 Kaihua Zhao Educational Fund for Physics	2010
求索奖学金 Truth-seeking Scholarship	2011
张文新教育基金 Wenxin Zhang Educational Fund for Physics	2011
海鸥奖学金 Ou Hai Scholarship	2011
北大物理 91 基金 ’91 Physics Class Fund	2011
沈克琦物理教育基金 Keqi Shen Educational Fund for Physics	2011
物理学院学生发展基金 PKU Physics Students Development Fund	2011
北大物理百年专项基金 The Centennial Celebration Fund for Physics at PKU	2012
近代物理研究所奖学金 Institute of Modern Physics Fund	2012
北大物理 85 念恩奖学金 ’85 Physics Class Fund	2012
北京大学物理学院紧急救助基金 Emergency Aid for Physics at PKU	2013
北大物理新楼报告厅座椅认捐基金 PKU Physics Lecture Hall Chair Donation Fund	2013
北京大学物理 79 级捐赠园林基金 ’79 Class Fund for Garden Donation	2013
北京大学物理新楼视频会议室专项基金 PKU Physics Video Meeting Room Fund	2013
北京大学物理新楼楼前花园基金 Physics Building Front-garden Fund	2013
北大合伙人奖学金 PKU Partnership Fund	2013

北京大学物理新楼“7802 会议室”专项基金 PKU Physics 7802 Meeting Room Fund	2013
1978 级原子核物理校友奖励基金 ’78 Nuclear Physics Class Fund	2013
北京大学物理学院兴诚本科生科研基金 PKU Xingcheng Fund	2014
北大物理 1980 级校友捐赠基金 ’80 Physics Class Fund	2014
北大物理图书馆新馆阅览室基金 PKU Physics New Library Reading Room Fund	2014
北大物理中 212 会议室座椅认捐基金 PKU Physics Room 212 Middle Building Chair Donation Fund	2015

合作与交流
Cooperation

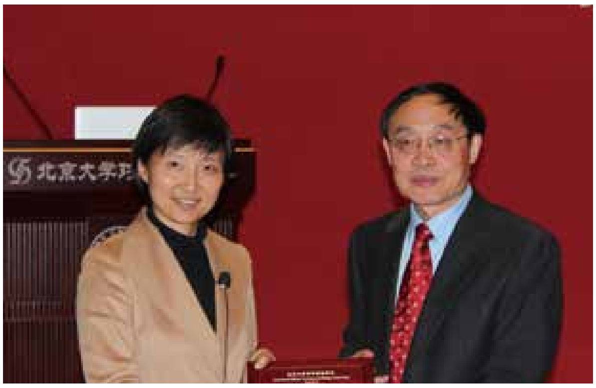
一、格物明理，接轨国际 The Centennial Physics Lectures

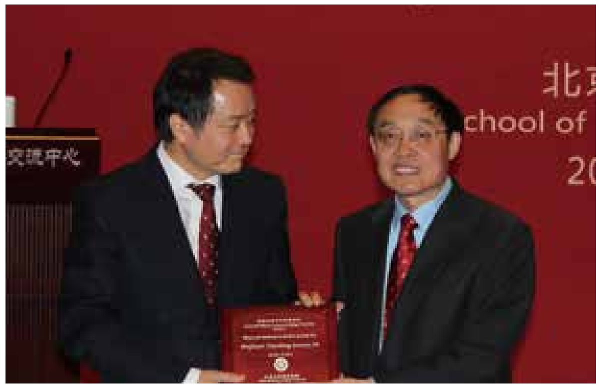
2013 年度成功举办“北大百年物理讲坛”第七讲和第八讲。第七讲邀请到美国斯坦福大学物理科学“保罗•派格特讲席教授”沈志勋教授做了题为“光电效应——一个发明与创新的世纪”的学术报告。

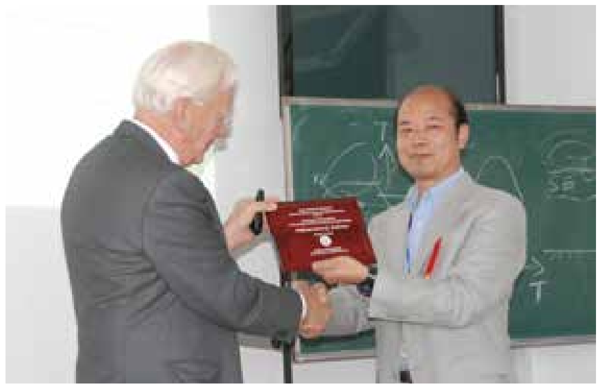
In 2013, the school held the 7th and 8th sessions of The Centennial Physics Lectures. The 7th lecture was titled “Photoelectric Effect—A Century of Discovery and Innovation” given by the “Paul Pigott Professor” Prof. Zhixun Shen in the physical sciences of Stanford University.

第八讲邀请到三位哈佛大学教授庄小威、谢小亮和 James G. Anderson 分别作了三场精彩的学术报告。

The 8th lecture was jointly given by Prof. Xiaowei Zhuang, Prof. Xiaoliang Xie and Prof. James G. Anderson with Harvard University.







2014 年度成功举办“北大百年物理讲坛”第九至十二讲。第九讲邀请到诺贝尔物理学奖获得者、荷兰理论物理学家、乌得勒支大学 Gerard 't Hooft 教授和基础物理奖获得者、美国实验物理学家、加州大学圣巴巴拉分校 Joseph Incandela 教授论述学科前沿问题。

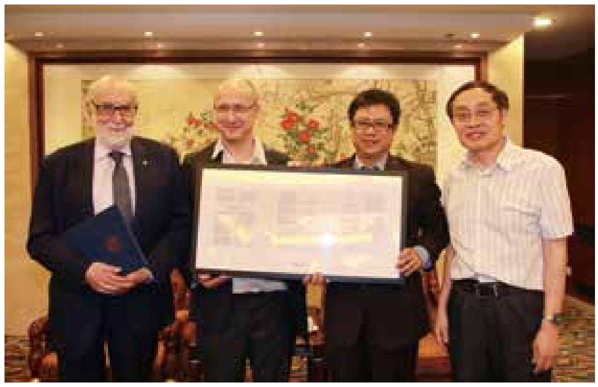
In 2014, the school held the 9th to 12th sessions of The Centennial Physics Lectures. The 9th lecture invited the Nobel laureate in physics Prof. Gerard ‘t Hooft and winner of the Basic Physics Award Prof. Joseph Incandela.

第十讲邀请到美国科学院院士、宾州州立大学 Moses Chan 教授与学院师生深入交流。

The 10th lecture was given by Prof. Moses Chan, fellow of the American Academy of Sciences with the State University of Pennsylvania.

第十一、二讲同时纳入北京大学“大学堂”顶尖学者计划，由北京大学国际合作部联合承办，邀请到诺贝尔物理学奖获得者、比利时理论物理学家、比利时布鲁塞尔自由大学 François Baron Englert 教授和诺贝尔物理学奖获得者、美国麻省理工大学 Frank Wilczek 教授作学术报告，并与北大师生开展合作与交流。

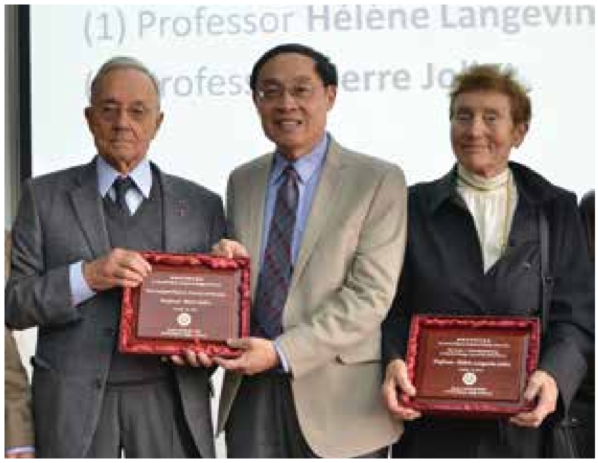
The 11th and 12th lectures were included into the PKU Global Fellowship program. We invited the Nobel laureates in physics Profs. François Baron Englert and Frank Wilczek for lectures and workshops.



二、邀请报告与合作交流　Invited Talks and Exchange Activities

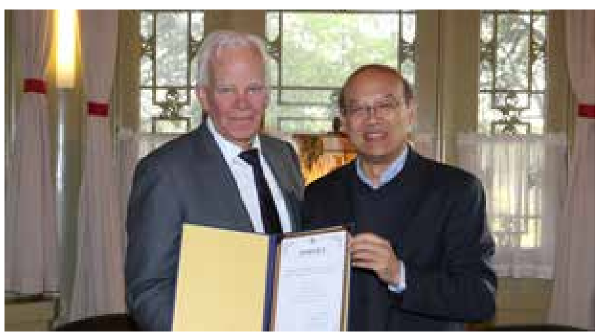
2013 年度学院荣幸邀请到法国著名学者核物理学家埃莱娜 • 朗之万 • 约里奥教授和生物学家皮埃尔 • 约里奥教授来校报告。埃莱娜曾担任过法国科研中心核物理委员会主席，皮埃尔是法国科学院院士、曾担任过法国总理的科学顾问。他们的父母是 1935 年诺贝尔奖获得者约里奥 - 居里夫妇，他们的外祖父母是 1903 年诺贝尔奖获得者皮埃尔 • 居里与 1903 年和 1911 年两度诺贝尔奖获得者玛丽 • 居里。

In 2013, the school invited the famous French scholars Elena Lang's Joliot and Pierre Joliot to give lectures at PKU. Their parents are the 1935 Nobel laureates the Joliot Curie couple, and their grandparents are the 1903 and 1911 Nobel laureates Pierre Curie and Marie Curie.



2014 年度还邀请哈佛大学 James G. Anderson 教授作北京大学“大学堂”顶尖学者计划报告，并与物理学院和环境科学与工程学院的部分师生深入座谈，由王恩哥校长为其颁发北京大学客座教授聘书。

In 2014, the school invited Prof. James G. Anderson to give the PKU Global Fellowship lecture and exchange with PKU faculty and students. Prof. Anderson was awarded the appointment letter of “PKU Guest Professor.”



北京大学物理学院代表团于 2013 年 1 月 27-30 日访问台湾大学理学院，并举行“台湾大学理学院与北京大学物理学院科研教学合作研讨会”。1 月 28 日举行正式开幕并设分会场，在教学（含实验），高能与天文，大气科学与半导体、磁性、光学、超导等领域分别安排学术报告和交流，促进双方加深了解，建立实质性合作。

The school sent its visiting delegation to the College of Sciences of Taiwan University and they jointly held the Symposium on Research and Education Cooperation in January 2013.

2013 年 1 月，法国东巴黎大学校长 Dominique Perrin 教授、副校长 Didier Degny 教授和科研主任 Tarik Bourouina 教授访问我院。北京大学物理学院院长谢心澄教授、副院长王宇钢教授和电子显微镜实验室主任俞大鹏教授接待了来访外宾，并举行亲切座谈。

In January 2013, Prof. Dominique Perrin, President of University of East Paris led a delegation to our school.

2013 年 4 月，《自然通讯》期刊中国执行主编 Ed Gerstner 博士访问学院。北京大学物理学院院长谢心澄教授、电子显微镜实验室主任俞大鹏教授以及物理学院十余位年轻教师在物理楼南 208 会议室接待了外宾，并与外宾亲切座谈。

In April 2013, Dr. Ed Gerstner, Chief Managing Editor in China of Nature Communications met with Prof. Xincheng Xie, Dean of the school.

2013 年 4 月，英国杜伦大学物理系主任 Martin Ward 教授以及 Richard Myers 教授来访，与学院就本科生联合培养探讨合作可能。

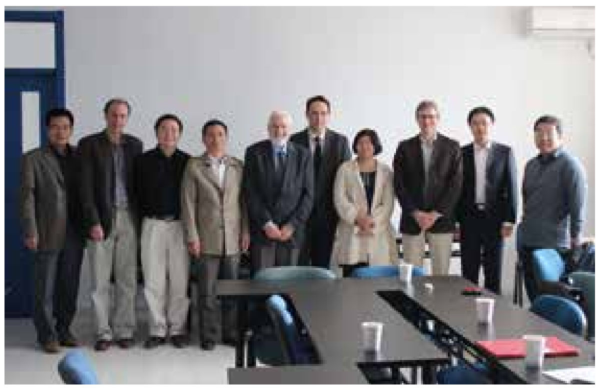
In April 2013, Prof. Martin Ward, Dean of Physics Department of Durham University visited our school and held a discussion on joint cultivation of undergraduate students.

北京大学与德克萨斯大学奥斯汀分校于 2013 年 5 月在物理学院量子材料科学中心举办了物理学术交流会。此次会议基于双方签订的交换生协议，以学术报告和教师间个人交流等方式，寻找共同兴趣，期待在研究小组间启动交流合作。

In May 2013, the University of Texas at Austin and PKU jointly held a physics academic exchange workshop at the International Center of Quantum Materials.

2013 年 6 月，与谢菲尔德大学签署“建立 III 族氮化物半导体联合研究中心的协议”。

In June 2013, the University of Sheffield and our school co-signed an agreement on setting up a joint research center.



2013 年 9 月，比利时布鲁塞尔自由大学副校长 Pierre Marage 等四人访问物理学院。北京大学物理学院技术物理系主任许甫荣教授，副系主任冒亚军教授等四位教授接待了来访外宾。

In September 2013, Prof. Pierre Marage, Vice President of the Vrije Universiteit Brussel in Belgium visited our school.

2013 年 9 月美国非裔大学校长代表团一行 11 人参访我院重离子物理研究所。北京大学物理学院重离子物理研究所所长刘克新教授陪同参观了重离子所多个实验室。

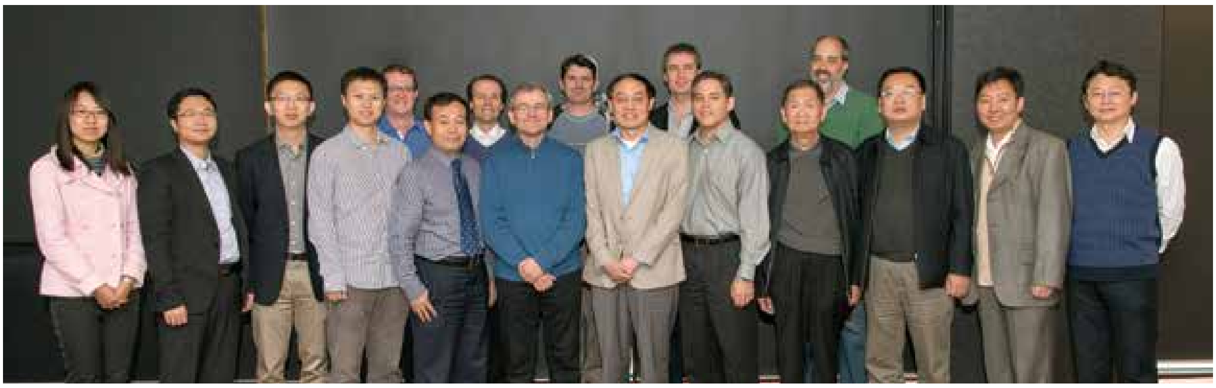
In September 2013, a delegation of the presidents of African American universities visited the Institute of Heavy Ion Physics of our school.

2013 年 10 月，法国高工两位副校长来访，物理学院副院长王宇钢教授出席会见。

In October 2013, two vice presidents of the Superior National University of Arts and Technologies visited our school.

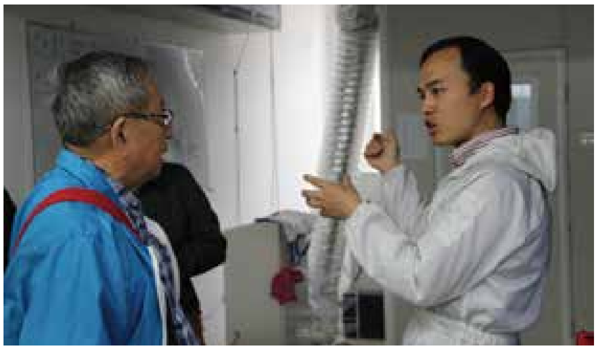
2013 年 11 月，北京大学物理学院一行九人出访澳大利亚，并对莫纳什大学（Monash）、澳大利亚国立大学（The Australian National University）、昆士兰大学（Queensland University）等三所大学进行访问。

In November 2013, the school sent its visiting delegation of 9 to the Monash University, the Australian National University, and the Queensland University in Australia.



2014 年 10 月，美国国家航空暨太空总署退休科学家丘宏义博士访问学院。北京大学物理学院院长谢心澄教授接待了丘博士，王新强教授参加了接待，并陪同参观量子中心、光学所和凝聚态所部分实验室。

In October 2014, Dr. Hongyi Qiu, retired scientist of National Aeronautics and Space Administration met with Prof. Xincheng Xie, Dean of the school, and visited the school labs.



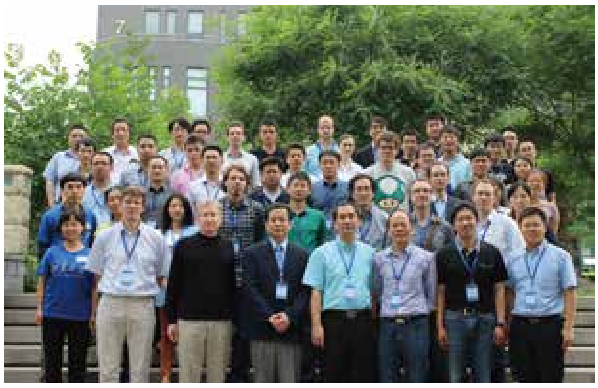
2014 年 10 月，台北市立第一女子中学数理资优班近 60 人到物理学院参观学习。学院副院长刘玉鑫教授代表学院接待了来访团。张朝晖教授、刘春玲副教授、廖慧敏讲师分组带领同学们参观了普物教学实验室，介绍实验室研究内容和进展，并与同学们进行交流。

In October 2014, a delegation of 60 from the science class of Taipei First Girls High School visited the school and exchanged with PKU students.

三、国际 / 港澳台会议 International/Hong Kong/Macao/Taiwan Conferences

2013 年 5 月，由北京大学承办的第三届“光学微腔及其应用国际研讨会”在北京大学中关新园召开。讨论会吸引了来自中国、美国、韩国、德国、法国、日本和澳大利亚的 60 余位代表参加。

The Third International Workshop on Microcavities and Their Applications was held at PKU in May 2013. More than 60 representatives from China, US, Korea, Germany, France, Japan and Australia attended the conference.



2013 年 6 月，“固体中的马约拉纳费米子国际会议”于北大物理百年之际在北京大学中关新园顺利召开。会议主办方是物理学院量子材料中心。

The Majoranas in Solid State Workshop was held at PKU in June 2013.

由北京大学和澳大利亚斯威本科技大学联合主办的“第三届绿色光子学国际研讨会”于 2014 年 1 月在澳大利亚墨尔本成功举办。

The 3rd International Symposium on Green Photonics, co-organized by PKU and Swinburne University of Technology, was held in Australia in January 2014.

2014 年 1 月，“第三届海峡两岸纳米光子学研讨会”在台南成功大学顺利召开。来自台湾大学、新竹交通大学、成功大学和北京大学、中科院物理所、半导体所、清华大学、浙江大学等 30 余位学者与会并做学术报告。

The 3rd Cross-Strait Symposium on Nano-Photonics was held in National Cheng Kung University in January 2014.

2014 年 10 月，50 余位中日学者参加了我校科维理天文与天体物理研究所举办的“夸克与致密星”学术研讨会，其中日方学者近 20 位。

The Kavli Institute of Astronomy and Astrophysics held the “Quarks and Compact Stars 2014” workshop in October 2014. The workshop attracted more than 50 participants, among them 20 are from Japan.

第 21 届国际自旋物理大会（SPIN2014）于 2014 年 10 月在北京召开。会议由北京大学主办，得到清华大学、科学院高能物理所和理论物理所、国际国内多家著名研究机构和大学、以及国家自然科学基金委的大力支持和赞助。

The 21st International Symposium on Spin Physics 2014 was held by PKU in October 2014.

2013 年，美国能源部批准资助中国 - 美国奇特核物理理论研究所，旨在进一步推动中国与美国核物理界在放射性核束物理方面的合作研究。这是美国能源部批准资助的第三个类似合作研究机构（第一个是美日 JUSTIPEN，第二个是美法 FUSTIPEN）。

In 2013, the United States Department of Energy (DOE) granted the establishment of the China-U. S. Theory Institute from Physics with Exotic Nuclei (CUSTIPEN) to promote the cooperation between the China and U.S. nuclear physics communities on radioactive nuclear physics.

四、对外宣传：

2013 年度，学院设计完成《物理学院 2011-2012 年度报告》（中英双语版），涵盖学院人事概况、下属机构、系所中心研究亮点、校友与基金、合作与交流等内容，有力推动学院对外交流工作的开展，为促进科研成果的输出和提升学院的国际地位作出积极努力。

In 2013, the school issued *The Bi-annual Report 2011-2012* in the bilingual edition. The report covered the school's Personnel, Divisions, Research Highlights, Students, Alumni and Funds, Cooperation, Awards and Honors. The purpose of the report was to promote international exchange and cooperation of the school and elevate its academic status in the international physics community.

奖励与荣誉
Awards & Honors

2013 年度：
In 2013,

- “量子物质科学协同创新中心”通过教育部组织的专家认定并获得财政部、教育部的专项经费支持
  “The Collaborative Innovative Center of Quantum Matter” was officially approved by the Ministry of Education and was granted financial support from the Ministry of Finance and the Ministry of Education
- 欧阳颀、龚旗煌当选为中科院院士
  Qi Ouyang and Qihuang Gong were elected Academicians of the Chinese Academy of Sciences
- 孙庆丰被评聘为长江特聘教授
  Qingfeng Sun was appointed the Yangtze River Scholar by the Ministry of Education
- 陈斌、施均仁入选杰出青年基金
  Bin Chen and Junren Shi were awarded the National Funds for Distinguished Young Scientists
- 冯济、林熙、彭良友、任泽峰、施可彬获批优秀青年科学基金资助
  Ji Feng, Xi Lin, Liangyou Peng, Zefeng Ren and Kebin Shi were awarded the National Funds for Excellent Young Scientists
- 颜学庆入选科技部创新人才推进计划青年领军人才
  Xueqing Yan was included into the Young Leading Talents in the Innovative Talents Promotion Plan initiated by the Ministry of Science and Technology
- 陈佳洱获蔡元培奖
  Jia’er Chen was awarded “the Cai Yuanpei Medal”
- 秦国刚获国华杰出学者奖
  Guogang Qin was awarded the Guohua Distinguished Scholar Medal
- 孟智勇获第十届中国青年女科学家奖
  Zhiyong Meng won the Chinese Young Woman Scientist Medal

- 孟杰课题组获 2013 年度高等学校科学研究优秀成果奖（科学技术）自然科学奖一等奖
  Jie Meng’s Group was awarded the first-class Natural Science Award of Higher Education Science Research Excellent Achievements

- 赵光达、朱星分别指导的学生马滟青、方哲宇的毕业论文被评为全国优秀博士论文
  Yanqing Ma (Guangda Zhao as mentor) and Zheyu Fang (Xing Zhu as mentor) won the National Excellent Doctoral Dissertation Awards

- 叶沿林当选中国核物理学会新一届理事长
  Yanlin Ye was elected Chairman of the China Nuclear Physics Society

- 数学物理方法、量子力学、力学、普通物理实验和电磁学在原国家精品课基础上被评为全国资源共享课
  “Method of Mathematics and Physics,” “Quantum Mechanics,” “Mechanics,” “General Physics Laboratory” and “Electromagnetism” were chosen as National Resource Sharing Courses

2014 年度：
In 2014,

- “介观光学和飞秒光物理”创新群体龚旗煌院士和肖云峰研究员研究项目“单个纳米颗粒光学检测新原理研究”入选 2014 年度“中国高等学校十大科技进展”
  Qihuang Gong and Yunfeng Xiao’s research program won the Ten Major Scientific Progresses of Higher Education in China

- 王恩哥院士获 2014 年度陈嘉庚数理科学奖
  Academician Enge Wang was awarded the Chen Jiageng Mathematics and Physics Science Medal

- 杨应昌院士在第 23 届国际稀土永磁会议上获颁杰出成就奖
  Academician Yingchang Yang won the Distinguished Achievement Medal at the 23rd International Workshop on Rare Earth Permanent Magnets

- 王新强、刘运全、吴飙被聘为长江特聘教授
  Xinqiang Wang, Yunquan Liu and Biao Wu were appointed the Yangtze River Scholars by the Ministry of Education

- 孟智勇获杰出青年基金
  Zhiyong Meng was awarded the National Funds for Distinguished Young Scientists

- 李新征、林金泰、吕国伟、方哲宇获批优秀青年科学基金资助
  Xinzheng Li, Jintai Lin, Guowei Lv and Zheyu Fang were awarded the National Funds for Excellent Young Scientists

- 刘运全入选科技部创新人才推进计划青年领军人才
  Yunquan Liu was included into the Young Leading Talents in the Innovative Talents Promotion Plan initiated by the Ministry of Science and Technology

- 李焱等获 2014 年度高等学校科学研究优秀成果奖（科学技术）自然科学奖二等奖
  Yan Li's Group won the second-class Natural Science Award of Higher Education Science Research Excellent Achievements

- 张国义等获 2014 年度高等学校科学研究优秀成果奖（科学技术）科技进步奖二等奖
  Guoyi Zhang's Group won the second-class Science and Technology Progress Award of Higher Education Science Research Excellent Achievements

- 龚旗煌负责“极端光学”研究团队入选科技部重点领域创新团队
  Qihuang Gong's Group was included into the Key Field Innovative Teams by the Ministry of Science and Tchnology

- 李焱获得“全国优秀科技工作者”称号
  Yan Li was entitled the “National Excellent Science and Technology Worker”