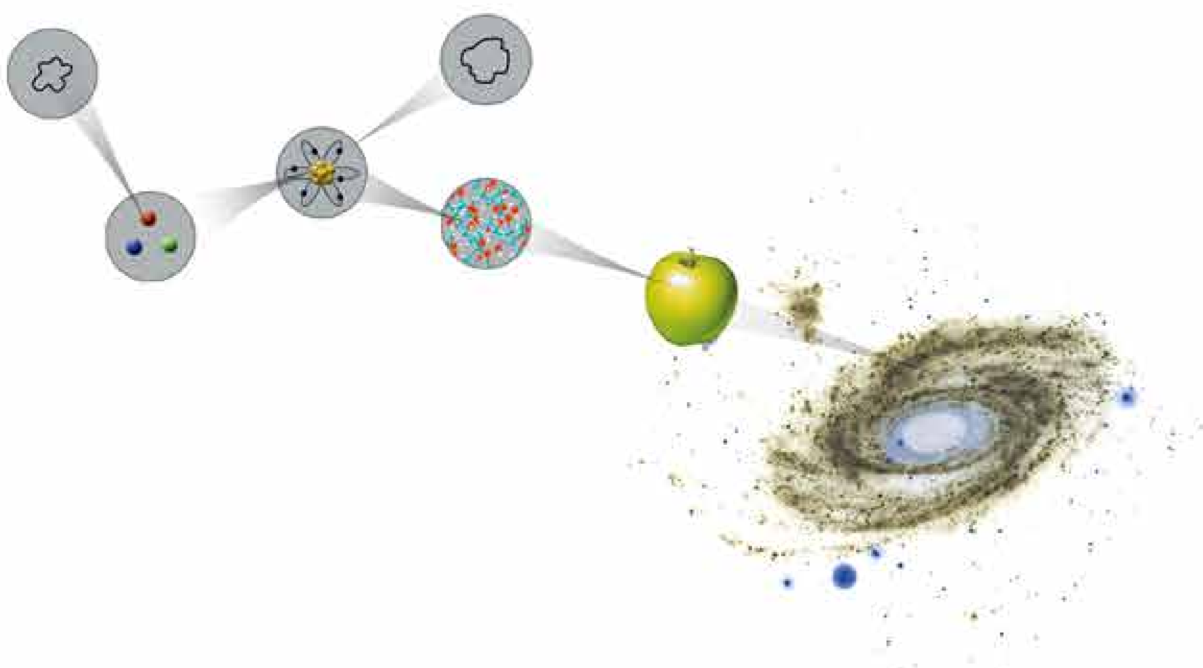

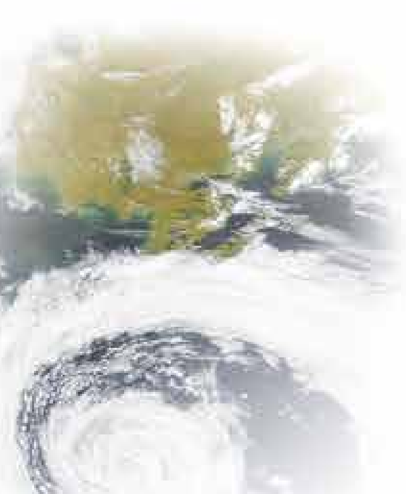

2017–2018 年报 Bi-annual Report

2017-2018

北京大学物理学院

SCHOOL OF PHYSICS, PEKING UNIVERSITY

年报

Bi-annual Report

学院简介
Introduction of School of Physics, Peking University

北京大学1913年设立物理学门，我国物理学本科教育从此开始。1919年更名为物理系。抗战时期，北大、清华、南开三校物理系合并于西南联合大学。1952年全国院系调整后，北京大学物理系集原北大、清华、燕大三校物理精英成为我国高校实力最强的物理重镇，并先后创办或参与创建全国高校第一个核科学专业、半导体物理专业、地球物理专业、微电子专业等。2001年，北京大学物理学院在原物理系以及重离子物理研究所、技术物理系核物理专业、地球物理系大气物理与气象专业、天文系的基础上组建成立。

在百余年的历史征程中，北京大学物理学科群星璀璨、薪火相传。这里曾聚集了饶毓泰、吴大猷、丁燮林、朱物华、周培源、叶企孙、王竹溪、胡宁、黄昆等一大批中国物理界的领军人物，先后联合培养了郭永怀、彭桓武、杨振宁、邓稼先、朱光亚、于敏、李政道、周光召等众多享誉世界的杰出科学家。在这里学习或工作过的中国科学院院士有110多位，中国工程院院士12位。在我国23位“两弹一星”元勋中，有12位是北京大学物理学院的校友。这里也是我国高校中校友当选美国物理学会会士（Fellow）最多的物理院系。

今天的北京大学物理学院师资力量雄厚，吸引和汇聚了一大批国内外顶尖学者。学院现有包括21位中国科学院院士（含11位双聘院士），13位“长江计划”特聘教授，38位国家杰出青年基金获得者，19位优秀青年科学基金获得者，“万人计划”百千万工程领军人才1位、科技创新领军人才5位、青年拔尖人才4位、教学名师1位，5个基金委创新研究群体，2位国家级名师奖获得者，1个国家级优秀教学团队在内的200余人组成的教学科研队伍。

学院下设2个教学实体单位（基础物理教学中心、基础物理实验教学中心），9个研究系所（理论物理研究所、凝聚态物理与材料物理研究所、现代光学研究所、重离子物理研究所、技术物理系、天文学系、大气与海洋科学系、国际量子材料科学中心、科维理天文与天体物理研究所），同时依托学院建立了人工微结构和介观物理国家重点实验室、核物理与核技术国家重点实验室、医学物理北京市重点实验室、李政道高能物理研究中心等多个科研机构，研究方向涵盖了物理科学及相关的主要领域，并建有北京大学电子显微镜专业实验室。

学院现有物理学、大气科学、天文学、核科学与技术 4 个一级学科博士点及博士后流动站，物理学、大气科学为国家一级重点学科（含理论物理、凝聚态物理、光学、粒子物理与原子核物理、大气物理学与大气环境、气象学等 6 个国家二级重点学科），天体物理、核技术及应用为国家二级重点学科。学院致力于培养具有国际视野和创新精神，具备扎实理论基础和突出科研能力的优秀人才，每年招收约 200 名本科生，200 名研究生和 30 名博士后，吸引着来自全国各地最优秀的学子，形成了一套科学完整的高层次人才培养体系。物理学院毕业生基础扎实宽厚、综合素质突出，广泛活跃在国内外高等院校、科研机构、政府部门、金融实业等领域。

学院科研工作以国际科学前沿和国家战略需求为导向，既鼓励原创性基础研究，也积极推进面向国家重大科技需求的应用研究，同时提倡不同优势学科之间的交叉拓展，取得了一大批在国内外具有重要影响的研究成果。近 5 年来承担和完成了 300 余项国家科研项目，包括多项国家重点基础研究发展规划（“973”计划）项目、国家高技术研究发展计划（“863”计划）项目、国家重大科学研究计划项目等。学院每年以北京大学为第一作者单位发表 SCI 论文约 500 篇，获得和申请国家发明专利 20 多项。学院的科研和教学成果获得包括国家自然科学奖、国家科技进步奖、国家级教学奖、国家精品课程等在内的多项国家级奖励。

面对新的机遇和挑战，北京大学物理学院在学科布局、队伍建设、人才培养、学术交流、对外合作、基础设施等各个方面迈开新的步伐：着力引进和培养杰出的学科带头人和优秀的青年后备人才，新增多位“长江学者”和“百人计划”研究员；继续探索和完善素质教育培养体系，建设“未名物理学子班”；进一步活跃学术研讨氛围，创办“北京大学百年物理讲坛”、“格致青年学术论坛”等高端学术讲座；广泛建立与国内外一流大学和科研机构的合作关系，更大范围提升物理学院的国际影响力；大力推进基础设施建设，改善学院教学科研环境，物理学院园区改造已于 2013 年北大物理百年时完成。

今天的北京大学物理学院，秉承百年北大的优良传统和深厚文化底蕴，着力构建和谐奋进的环境氛围，正在向着“完善制度，凝聚人才；前瞻布局，卓越教学；夯实基础，再创辉煌”的总体目标坚实奋进，努力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人才培养和科学研究中心。

In 1913, the “WuLi Men” (physics division) was established at Peking University, and this was later renamed the Department of Physics in 1919. With the reorganization of the Chinese system of higher education in 1952, the new Physics Department of Peking University was created from the merger of the physics departments of Peking University, Tsinghua University and Yenching University. This became the premier center for physics in China. The School of Physics was established in 2001, and includes not only the traditional fields of study in physics, but also related physical sciences. Today, the School of Physics includes Physics, Astronomy, Atmospheric & Oceanic Sciences, and Nuclear Science & Technology and consists of nine research institutes/departments, two teaching centers and several high-level laboratories, including the State Key Laboratory for Artificial Microstructure and Mesoscopic Physics and the State Key Laboratory of Nuclear Physics and Technology.

学院简介 | *Introduction of School of Physics, Peking University*

It has been over 100 years since Peking University established its Department of Physics. The Department’s founding in 1913 was not only an announcement of the importance that Peking University placed on the physical sciences, but also a milestone in the development of modern science in China. One hundred years on, the School has made distinguished contributions to the nation and to the world in both education and academia. As it embarks on its second century, the Peking University School of Physics extends a warm welcome to distinguished scholars and outstanding young students from China and abroad who wish to join its ranks.

To celebrate its centennial, the School of Physics creates the distinguished lecture series: Centennial Physics Lectures at Peking University starting in 2010. The lecture series will be held once each semester. Eminent scholars around the world will be invited to present lectures on both fundamental and cutting-edge problems in physics, astronomy, and atmospheric and oceanic sciences. We hope that this lecture series will establish a thought-provoking forum, stimulate lively and topical intellectual debates, strengthen global and interdisciplinary collaborations, promote the advancement of physical sciences, extend the distinguished and innovative scholarly tradition at Peking University.

The Peking University School of Physics now has the following divisions and related research institutes.

- Institute of Theoretical Physics
- Institute of Condensed Matter and Material Physics
- Institute of Modern Optics
- Institute of Heavy Ion Physics
- Department of Technical Physics
- Department of Astronomy
- Department of Atmospheric and Oceanic Sciences
- Teaching Center for General Physics
- Teaching Center for Experimental Physics
- Electron Microscopy Laboratory
- International Center for Quantum Materials
- Kavli Institute for Astronomy and Astrophysics
- State Key Laboratory for Artificial Microstructure and Mesoscopic Physics
- State Key Laboratory of Nuclear Physics and Technology
- Beijing Key Laboratory of Medical Physics and Engineering
- Center for High Energy Physics
- Institute of Nuclear Science & Technology

Today, the School of Physics has about 200 faculty and staff, including 21 Academicians of the Chinese Academy of Sciences (double employment included), 21 “Cheung Kong” Scholars, 38 National Distinguished Young Scholars and 19 Excellent Young Scientists awarded by the National Natural Science Foundation of China (NSFC). There are 5 innovative research groups sponsored by NSFC.

The School of Physics grants Bachelor of Science, Master of Science, and Doctor of Philosophy degrees. Around 200 undergraduate students, 200 graduate students and 30 postdoctoral fellows are admitted each year by the

School of Physics. Most undergraduate students pursue advanced studies after finishing their Bachelor degrees, and about one-third of them go to leading international universities for their advanced study.

The School of Physics has a tradition of teaching excellence in both graduate and undergraduate courses. Faculty members have received several National Teaching Awards, along with more than 30 teaching awards at provincial and ministerial levels. Scholars in the School of Physics published more than one hundred textbooks and monographs since 1991.

Research in the School of Physics is devoted not only to the frontiers of fundamental physics but also to the innovation of advanced technology. The School plays a leading role in planning and executing regional, national, and international scientific research programs. Major research fields include: high energy physics, astrophysics and cosmology, radioactive nuclear physics, high energy-density physics, key technologies for advanced light sources and particle beams, the interaction of particle beams with materials, mesoscopic semiconductor light emission and laser physics, ultra-fast physics, optical properties of artificial microstructures and mesoscopic devices, electro-magnetic properties of mesoscopic functional systems, mesoscopic theory and material computation, high-temperature superconductivity physics and devices, nano-material and devices, near-field optics, quantum materials and quantum manipulation, soft condensed matter physics, biophysics, medical physics and imaging, atmospheric physics and the environment, meteorology and climate change, physical oceanography, and many others. Scholars in the School were awarded several National Science & Technology Progress Awards in the past five years. During this period, the School has more than 300 on-going and completed research projects, including national basic research programs (“973” projects), national high technology research and development programs (“863” projects) and more than 20 key projects of the NSFC. Research funding in the School has progressively increased in recent years.

The School is involved in a wide range of international activities. A number of faculty members serve as committee members in many international scientific organizations and as editors for leading international journals. Peking University participates in many international collaborations, in particular the world’s largest high-energy physics project, LHC-CMS, as well as a number of other projects, such as RIKEN and KEK in Japan, GSI and DESY in Germany, and JLab and ANL in the United States. The School of Physics organizes various international conferences and international summer schools and seminars.

There has been rapid improvement in the facilities and equipment for scientific research in recent years, with a total expenditure of more than 200 million RMB. This has resulted in a number of flagship instruments, including a seven-femtosecond CE-phase-stabilized laser amplifier system, a molecular beam epitaxy system, a metal-organic chemical vapor deposition system, a focused ion beam workstation, and four electrostatic ion accelerators.

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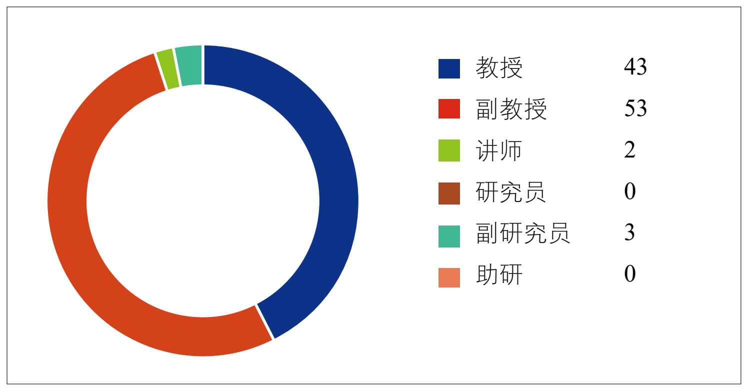

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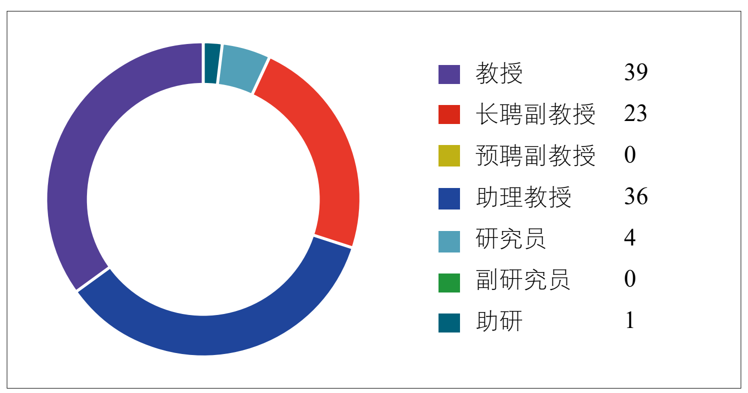

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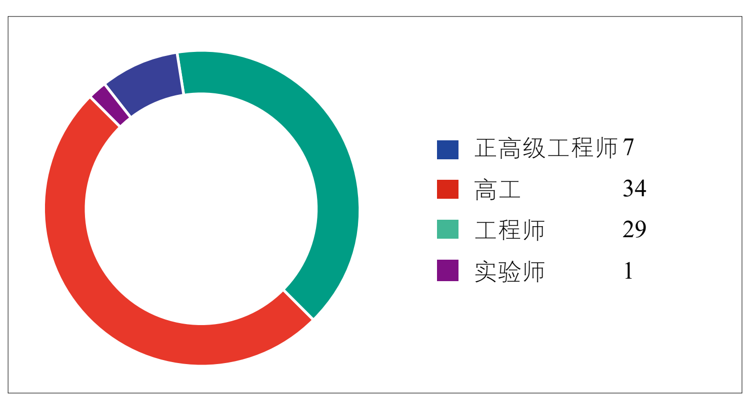

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下属机构
Divisions

- 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
- 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 Peking University Electron Microscopy Laboratory
- 量子材料科学中心 International Center for Quantum Materials
- 北京大学科维理天文与天体物理研究所 Kavli Institute for Astronomy and Astrophysics
- 人工微结构和介观物理国家重点实验室 State Key Laboratory for Artificial Microstructure and Mesoscopic Physics
- 核物理与核技术国家重点实验室 State Key Laboratory of Nuclear Physics and Technology
- 高能物理研究中心 Center of High Energy Physics

系所中心研究亮点 | *Highlights*

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 19 人，其中教员（含教授、副教授、研究员等）18 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 19 members in the institute with 18 faculty members and one administrative staff. The research fields include string and cosmology, particle physics theory, hadronic physics, nuclear physics, condensed matter and statistical physics that cover from the scale of the universe down to microscopic scales of elementary particles.

一、QCD 物质的剪切粘滞系数和体粘滞系数的温度依赖行为

众所周知，物理学研究的核心目标之一是揭示宇宙物质演化的规律，可见物质质量的起源，更具体地讲，费米子质量的起源，自然是其中的重大核心问题之一（在 20 世纪与 21 世纪之交，被列为“世纪大奖问题”）。按照现代物理学的观点，该问题是强相互作用物质相变问题。由于描述强项相互作用的性质和规律的动力学是量子色动力学，即简称的 QCD，因此人们称之为 QCD 相变问题。由于相变是非微扰相互作用所致，并且在非微扰层次上确定强关联非阿贝尔系统的有效热力学势的方案尚未建立，于是传统的通过分析系统的有效热力学势以确定相变（相边界曲线及临界点状态）的判据失效，于是人们建立了分析手征磁化率的新方案（例如，Phys. Rev. Lett. 106: 172301 (2011); Phys. Rev. D 94: 076009 (2016); 等）。

实验上，人们通过研究相对论性核核碰撞形成的“火球”物质的演化和观测分析统称为“中子星”的强相互作用物质形成的致密星体的性质和结构来进行实验研究。这些物质都是强关联的非阿贝尔系统，即 QCD 物质。从而，“火球”物质的演化和“中子星”的性质与结构都很强地依赖于 QCD 物质的输运性质。粘滞系数是表征物质输运性质的重要特征量，并提出剪切粘滞系数与熵密度的比值（η/s）可以作为 QCD 的手征相变的一个判据。然而，现有的不同理论模型方法对 η/s 随温度变化的行为给出相互矛盾的结果。关于体粘滞系数与熵密度的比值（ζ/s）随温度变化行为的理论（模型）结果之间的矛盾更尖锐。于是，直接在 QCD 连续场论层次上对于 QCD 物质的粘滞系数随温度变化行为的研究就很迫切。刘玉鑫课题组近来在这方面取得了重要进展。

已经熟知，QCD 物质的基本组分是夸克和胶子，在低温零净重子数情况下，夸克和胶子形成介子。由于最低能态的介子是 π 介子，因此人们常通过研究 π 介子物质的性质（包括高温时熔化为夸克胶子物质）而研究 QCD 相变。在 QCD 层面上，介子由四维协变的 Bethe-Salpeter 方程描述， 而对之求解需要由 QCD 的 Dyson-Schwinger 方程决定的完整的夸克传播子等作为输入。温度效应则由标准的虚时温度场论方法引入。在可以很好描述真空中的 π 介子的质量（m_π）和弱衰变常数（f_π）的参数下，计算得到 m_π 和 f_π 随温度变化的行为如图 1 的左栏所示。为研究 QCD 物质的强关联性质，需要计算 π-π 作用的标量道（δ 介子道）和矢量道（ρ 介子道）的行为。通过进一步求解 Roy 方程得到的 δ 介子和 ρ 介子的质量和共振宽度随温度变化的行为如图 1 的右栏所示。由图 1 易知，计算所得的这些介子的质量和共振宽度在零温下的结果都与实验结果很好符合。并且 m 由保持常量到随温度升高而增大的转变温度与由手征磁化率确定的手征相变（实际为连续过渡）赝临界温度 $T_{c;\chi}$ 也很好符合。根据稳定性的能量最低原理，人们称对应于 4 倍夸克组分质量（$4M_q$）与 m 及 m_O 相等时的温度为介子的熔化温度，亦即退禁闭相变温度 ($T_{c;d}$)。图 1 表明，$T_{c;d} > T_{c;\chi}$，由此知，在 $T_{c;\chi}$ 与 $T_{c;d}$ 之间的温区内，存在手征对称性恢复但夸克仍然禁闭的 quarkyonic 相。更精细的研究表明，此乃强子化时强子与夸克胶子物质之间有有限的弯曲分界面所致的过热现象，因此 quarkyonic 相是一个亚稳相。

由上述 π-π 作用的标量道和矢量道的行为可得到 π 介子的热宽度。进而利用基于输运理论一般规律的动力学方法（例如：Phys. Rev. Lett. 102: 121601 (2009)），可得到 QCD 物质的剪切粘滞系数和体粘滞系数随温度变化的行为。按照一般的温度场论方法可得系统的熵和熵密度。进而得到 η/s 和 ζ/s 随温度变化的行为。所得结果如图 2 所示。

由图 2 知，随着温度升高，到达 $T_{c;\chi}$ 时，η/s 和 ζ/s 都由单调减小转变为上升；再升高至 $T_{c;d}$ 时，η/s 的行为无明显变化、但 ζ/s 转变为下降。这说明，ζ/s 不仅可以作为手征相变的判据还可以作为退禁闭相变的判据。再者考虑硬热圈重求和效应可以明显压低手征对称性恢复的物质的 η/s 和 ζ/s 的数值，但不影响它们随温度变化的定性行为。

总之，这一工作率先直接在 QCD 层次上给出了 QCD 物质的粘滞系数及它们与熵密度的比随温度变化的行为，并说明 ζ/s 不仅可以作为手征相变的判据还可以作为退禁闭相变的判据。另外，这一成果已经发表在 Phys.Rev. D 97: 056011 (2018).

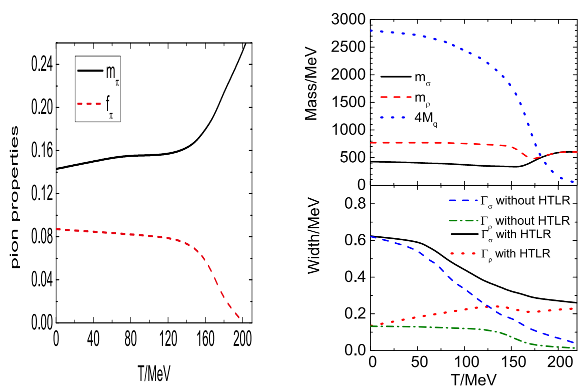


图 1. 介子的质量和衰变常数随温度变化的行为的计算结果（左栏）、δ 道和 ρ 道的质量与共振宽度及 $4M_q$ 随温度变化行为的计算结果（右栏）。

FIG. 1. Calculated temperature dependence of the pion'smass and decay constant (left panel), and those of the masses and widths of the δ - and ρ -channel resonances and that of the $4M_q$ (right panel).

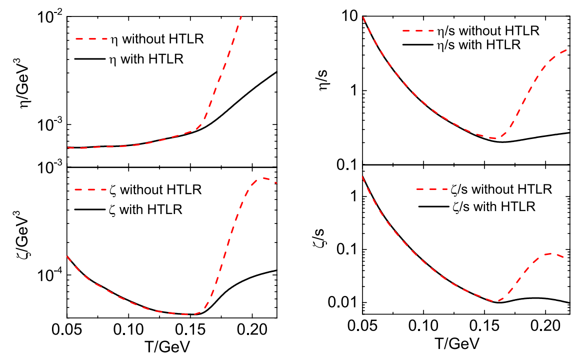


图 2. 剪切粘滞系数 η 和体粘滞系数 C 及它们与熵密度的比值随温度的变化行为的计算结果。

FIG. 2. Calculated temperature dependence of the shear viscosity η and the bulk viscosity ζ (left panel), and that of ratios to the entropy density (right panel).

系所中心研究亮点 | *Highlights*

I. Temperature Effect on Shear and Bulk Viscosities of QCD Matter

It has been known that the shear viscosity (η) and its ratio to the entropy density (s) could be a signature to identify the phase transitions of various kinds of matters (e.g., Phys. Rev. Lett. 97: 152303 (2006); Rep. Prog. Phys. 72: 126001 (2009); etc.). However, the T-dependence of the η /s of QCD matter is still controversial (e.g., Phys. Rev. Lett. 97: 152303 (2006); Phys.Rev. Lett. 115: 112002 (2015); Phys. Rev. Lett. 102:172302 (2009); Phys. Rev. Lett. 103: 172302 (2009);etc.). More serious contradictions exist in the results of the T-dependence of the ζ /s(e. g., Phys. Lett. B 663:217 (2008); Phys. Rev. Lett. 100: 162001(2008); Phys.Rev. Lett. 102: 121601 (2009);Phys. Lett. B 734:131(2014); Phys. Lett. B 747: 36 (2015); Phys.Rev. Lett.119: 042301 (2017); etc.). One may then doubt the validity for the η /s and ζ /s to label a phase transition,even the power of statistical physics principle to describe properties of the strong interaction matter. Looking over the schemes taken in previous investigations more carefully, one can recognize that exploring the problems via sophisticated QCD approaches is imperative.

It is known that QCD matter can be considered as a system consisting of quarks and antiquarks (most of them are conned to form pions, the lowest mass hadrons, at low temperature). By solving the Dyson-Schwinger (DS) equations of QCD, one can get the quark (antiquark) propagator. Taking the solution of the DS equation as input, one can solve the 4-d Poincare invariant Bethe{Salpeter equation of the pion. With the scheme and pa-rameters with which the mass and decay constant of pion in vacuum is described well, one obtained the tempera-ture dependence of the pion mass and the decay constant as shown in the left panel of Fig. 1. By solving the Roy equations which are a set of coupled integral equations of various resonance channels, one can get the masses and the widthes of the scalar and the vector channels(corresponding to δ -meson, ρ -meson, respectively). The obtained results (without and with the hard thermal loopresummation correction) are displayed in the right panel of Fig. 1. It is apparent that the masses and their widths of the resonances at zero temperature agree with exper-imental data very well. It is interesting that the point for the m_{δ} to get increasing coincides the pseudo-critical temperature of the chiral symmetry (T_c). Meanwhile,the point for the $4M_q$ to merge with the m_{δ} (and m_{ρ})is usually regarded as the melting point. These featureshint that the deconnement temperature is higher than the dynamical chiral symmetry restoration temperature.More detailed analysis manifests that such a phenomenon is in fact a superhot phenomenon. As a consequence, thequarkyonic phase is a metastable phase.

With the obtained resonance properties of the π - π scat-tering, one gets further the thermal width of pion. More-over, in the sprit of kinetic theory approach (Phys. Rev. Lett. 102: 121601 (2009)), one can get the viscosities of the system. The obtained results of the temperature dependence of the viscosities and that of the ratio to the entropy density are shown in Fig. 2. These obtained char-acteristic of the T-dependence of the ζ /s demonstrates distinctly that the ζ /s can identify not only the chiral phase transition but also the deconnement phase tran-sition.

In short, it is the first to give the temperature depen-dence of the shear and bulk viscosities and their ratios to the entropy density at the continuum QCD level, and show that the ζ /s can identify not only the chiral phase transition but also the deconnement phase transition. In addition, it should be mentioned that these results have been published in Phys. Rev. D 97: 056011 (2018).

二、用格点 QCD 探索高精度前沿并寻找超标准模型新物理

标准模型迄今已经得到了众多精确检验，寻找超出标准模型的新物理是当今粒子物理研究的主要目标之一。在高精度前沿，人们通过实验与理论的高精度对比来寻找新物理的迹象。在众多的实验当中，稀有 K 介子衰变被誉为寻找新物理的黄金衰变道之一。

要在理论上精确计算稀有 K 介子衰变宽度，需要非微扰地处理低能 QCD 贡献。格点 QCD 通过高性能并行计算，可以从 QCD 第一性原理出发，为理论预言提供精确的 QCD 输入。当前，一般的格点 QCD 计算主要围绕 2 点或 3 点关联函数以及局域强子矩阵元。要理论精确计算稀有 K 介子衰变的低能 QCD 修正，则需要用到 4 点关联函数，构造非局域强子矩阵元，这在格点场论领域属于全新的开始，也是极富挑战性的工作。冯旭课题组系统地发展出一整套方法，用于处理非局域强子矩阵元计算中不可避免的有限体积修正、低能中间态引起的指数发散以及两个有效算符临近导致的紫外发散等。在工作 Phys.Rev.Lett. 118, 252001 (2017) 中，冯旭课题组成功地在超级计算机上实现了稀有 K 介子衰变的计算，这在格点 QCD 领域是首次计算得到了 $K\to\pi\nu\bar{\nu}$ 的稀有衰变振幅。这些工作不仅为实验测量稀有 K 介子衰变提供了理论上的对比，也为后续用格点 QCD 去研究高阶电弱相互作用以及 4 点关联函数开辟了思路。

除此之外，冯旭课题组还与国内的同行合作，提出了长程核相互作用中宇称破坏的新定理，有望极大简化在格点 QCD 框架下对宇称破坏耦合常数的计算。相关工作发表在 Phys.Rev.Lett. 120, 181801 (2018) 上。

II. Exploration in high-intensity frontier and search for beyond-standard-model physics using lattice QCD

Standard model has demonstrated huge success by passing tremendous experimental tests. Search of new physics beyond standard model is one of the main goals of the current researches in particle physics. In high-intensity frontier, the signal of new physics can be verified by comparing the high-precision experimental measurements and theoretical predications. Among vast experiments, the rare kaon decays are considered as one of the golden decay channels to explore the new physics. To accurately determine the rare kaon decay rates from theories, the low-energy QCD contributions need to be calculated non-perturbatively and precisely. By using high-performance computing, lattice QCD can provide from first principles the accurate QCD inputs for the theoretical predication. Currently, the standard lattice calculations mainly focus on the 2- or 3-point correlation function and local hadronic matrix elements. On the other hand, the lattice QCD calculations of the rare kaon decay involve the construction of 4-point correlation functions and the nonlocal hadronic matrix elements, opening a new research frontier as well as making a great challenge in lattice QCD. The group of Xu Feng developed a series of approaches to deal with nonlocal matrix elements, including the corrections of finite-volume effects, the elimination of exponentially growing contamination from low-lying intermediate states and the subtraction of the ultraviolet divergences, which appear as the two effective operators approach each other. In the work Phys. Rev.Lett. 118, 252001 (2017), Feng's group has successfully implemented the lattice QCD calculation of rare kaon decay on the supercomputer and obtained the $K\to\pi\nu\bar{\nu}$ decay amplitude from lattice QCD for the first time. Such study not only provides a comparison between theoretical predications and experimental measurements, but also paves a way for the future lattice QCD studies on second-order electroweak interactions and the calculations of 4-point correlation functions. Besides, together with the collaborators, Feng' s group has proposed a novel soft-pion theorem for long-range nuclear parity violation, which can significantly simplify the lattice QCD computations of parity violating coupling constant. This work has been published in Phys.Rev.Lett. 120, 181801 (2018).

三、高温超导涡旋液态的磁化率和磁导率交点及超导薄膜电输运的动力学不稳定性

90 年代初以来，人们发现在高温超导体中，在略低于临界温度 Tc 的某一个温度以下， 磁化率不依赖外加磁场。 这种磁化率交叉点。的起源一直是一个谜， 理论上没有给出合适的解释。类似现象也在磁导率相关数据中被观测到。

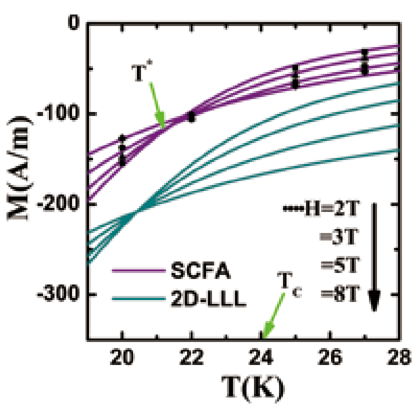
布拉耶夫斯基和他的合作者基于涡旋液相最低 Landau 能级近似理论框架下，理论上得出二维超导涨落存在磁化率交叉点。 布拉耶夫斯基的理论是基于最低 Landau 近似，但是事实上，实验观测到的磁化率交叉点是在最低 Landau 近似的有效区域之外，故这个理论被批评没有真正解释磁化率交叉点的存在。当然学术界惊奇的是，为什么"错误"的理论提供了对实验的如此好的描述。李定平课题组在文 [1] 中发展的理论，提供了这个谜团的解决方案。他们用自洽近似方法考虑了强非高斯热涨落，并包涵所有高阶 Landau 能级的作用。他们发现交叉温度正好处于二维三维过度区域。高于交叉温度，层和层之间失去关联，系统处于有效的二维系统，而在低于交叉温度，层和层之间是关联的，系统是有效的三维系统。

另外，人们实验发现， 超导薄膜在电流驱动下，低温区域，存在电压跳变，而在电压驱动下，低温区域，存在 S 型的 IV 曲线。在含时 Ginzburg-Landau 方程的框架下，李定平课题组在文献 [2] 中发展了超导薄膜中电子输运的非线性理论。他们利用自洽高斯近似，揭示了电流电压 V 曲线获得 S 形导致电流驱动的不稳定性的条件。他们证明，在二维中，这种不稳定性的出现是 Berezinskii-Kosterlitz-Thouless（BKT）跃迁的一个标志，他们已经通过氮化钛（TiN）薄膜的输运测量检测到了这种跃迁。他们的理论研究结果与实验结果比较好。

相关发表文献

1. Cheng Chi, XJ. Jiang, JF. Wang, Dingping Li, B. Rosenstein Phys. Rev. B 96, 224509 (2017);

2. L Qiao, Dingping Li, SV Postolova, AY Mironov, V Vinokur, B. Rosenstein, Scientific reports 8, 14104 (2018).



图一：文献 Phys. Rev. B 81, 054510 (2010) 测量的 LSCO 在不同磁场下，磁化率依赖温度的实验数据 (黑色点). 紫色曲线是自洽涨落近似理论的拟合曲线，而青葱色是最低朗道近似理论的曲线 .

Figure 1. Magnetization data of Phys. Rev. B 81, 054510 (2010) and theoretical fits (purple lines) of LSCO crystal for various values of H. The comparison between the fluctuation magnetization calculated using the self-consistent fluctuation approximation (SCFA) vs the 2D lowest Landau level (2D-LLL) approximation.

III. Intersection points of magnetization and magneto conductivity of vortex liquid phase in high Tc superconductors, and dynamical instability of the electric transport in superconducting thin films

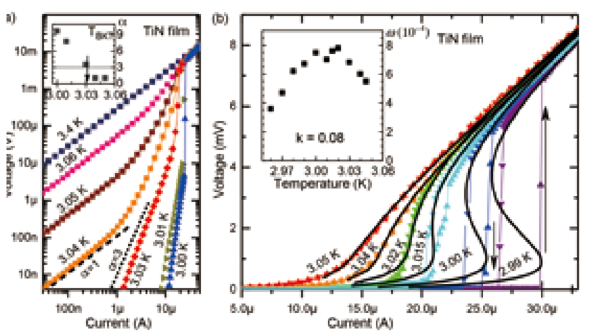
There were a long-standing puzzle of the origin of an intersection point at a temperature slightly below Tc in the magnetization temperature dependence in type II layered superconductors and the concurrent intersection point in magneto conductivity since earlier 90th. The intersection point in magnetization was derived by Bulaevskii and collaborators as a result of the 2D superconducting fluctuations in the framework of the lowest Landau level (LLL) theory of the vortex liquid phase. This derivation called for critique since Bulaevskii's treatment was done, in fact, outside the validity of the LLL approximation, although the surprise, why the "wrong" theory offers such a nice description of the experiment remained. In [1], Dingping Li's group offers a solution of the enigma demonstrating that the correct accounting for the strong non-Gaussian thermal fluctuations and all higher Landau levels within a self-consistent approach makes the situation effectively 2D just near the 2D-3D crossover where the intersection exists.

A nonlinear theory of the electronic transport in superconductors in the framework of the time-dependent Ginzburg-Landau equation was developed in the other work [2]. Li's group utilizes self-consistent Gaussian approximation and reveal the conditions under which the current-voltage V(I) dependence (I-V characteristics) acquires an S-shape form leading to switching instabilities. They demonstrate that in two-dimensions the emergence of such an instability is a hallmark of the Berezinskii-Kosterlitz-Thouless (BKT) transition that they have detected by transport measurements of titanium nitride (TiN) films. Their theoretical findings compare favorably with their experimental results.

Published papers:

[1] Cheng Chi, XJ. Jiang, JF. Wang, Dingping Li, B. Rosenstein Phys. Rev. B 96, 224509 (2017);

[2] L Qiao, Dingping Li, SV Postolova, AY Mironov, V Vinokur, B. Rosenstein, Scientific reports 8, 14104 (2018).



图二：TiN 薄膜在不同温度下的 I-V 曲线 . (a) 在双对数标度下的 I-V 曲线 . 点虚线对应 V ∝ , α = 3 , 虚线对应 α = 1. 插图显示 α 指数对温度的依赖关系，箭头标记的温度是 BKT 相变温度，对应 α = 3, TBKT 3.03 K. (b) 线性标度下的 I-V 曲线 . 实线是理论曲线 . 箭头标记电压的跳跃：电流从零增加时候，对应的是电压向上的跳跃；电流减少时候，电压会向下跳跃 .

Figure 2. The I-V curves of TiN thin film at different temperatures. (a) The I-V curves shown in double logarithmic scale. Dotted line corresponds to α = 3 in V ∝ dependence, dashed line corresponds to α = 1. Inset: temperature dependence of α exponent. Arrow marks the BKT transition temperature defined from the condition α = 3, TBKT 3.03 K. (b) The I-V curves are shown in the linear scale. Solid lines are the theoretical curves. Arrows mark the direction of the voltage jump: with the current increasing from zero–jump up; with the current decreasing to zero–jump down.

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 58 人，其中，长聘教授 7 人，长聘副教授 4 人，预聘制助理教授 6 人，老体制教授 12 人，副教授 14 人，工程技术人员 15 人。 研究队伍中包括，院士 2 人，长江特聘教授 5 人，国家杰出青年 7 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，微纳光子学及近场微区光谱，高温超导材料、物理与器件，纳米结构和低维物理，软凝聚态物理和生物物理，以及磁性物理和新型磁性材料。

There are 58 faculty members in the institute, consisting of 7 tenured professors, 4 tenured associate professors, 6 tenure-track faculty members, 12 full professors, 14 associate professors, and 15 engineering technicians. Among the senior researchers are 2 academicians of the CAS, 5 Chang Jiang scholar professors，and 7 national distinguished young scholars. The research fields covering a wide range include Wide bandgap semiconductor Physics and Devices, Theoretical Condensed Matter Physics, Nanosemidonductors and semiconductor photonics, Nanophotonics and Near-field Optics, High-temperature superconducting physics , materials and devices, Nanostructures and Low-Dimensional Physics, Soft Condensed Matter Physics and Biophysics, and Magnetism Physics and Advanced Magnetic Materials.

一、利用表面对称性破缺衬底实现分米级单晶六方氮化硼的制备

近年来，随着芯片制程的不断减小，传统硅基半导体器件中短沟道效应、热效应等问题日益明显，开发全新二维量子材料以实现变革性的器件应用已成为当前科技的前沿热点。高集成度器件应用必须基于大尺寸、高质量的单晶材料，因此二维单晶材料的制备研究具有重要的科学意义和技术价值。2017 年，北京大学物理学院王恩哥院士、俞大鹏院士、刘开辉研究员团队在单晶 Cu(111) 衬底上外延生长出米量级单晶石墨烯，首次实现了二维导体的晶圆制备（Xiaozhi Xu et al, Science Bulletin 62, 1074 (2017)）。但与石墨烯不同的是，六方氮化硼等绝大多数二维材料的晶格不具有中心反演对称性，在一般的外延生长中普遍存在孪晶晶界的问题。因此，探索全新生长机制以实现非中心反演对称性二维材料的晶圆级单晶制备是本领域所面临的重大挑战。

解决这一难题的关键在于衬底对称性的调控。北京大学物理学院王恩哥院士、俞大鹏院士、刘开辉研究员团队经过反复攻关，开发出一套利用表面对称性破缺的衬底外延非中心反演对称性二维单晶的新方法，成功的制备出分米量级的单晶六方氮化硼单层薄膜。研究成果以“Epitaxial growth of a 100-square-centimetre single-crystal hexagonal boron nitride monolayer on copper”为题发表在《自然》杂志上（Li Wang et al, Nature 570, 91 (2019)）。该方法通过专利保护的退火工艺将工业多晶铜箔转化为仅有 C1 对称性的铜 (110) 小角度倾斜晶面，利用六方氮化硼晶畴中硼型和氮型锯齿形边界与 Cu<211> 台阶耦合强度的差异，打破衬底表面的中心反演对称性，进而打破两个优势取向的能量简并。从而实现六方氮化硼晶畴的单一取向生长，并且无缝拼接为整片单晶（图 1）。该方法首次提出了利用对称性破缺衬底实现二维单晶生长的新思路，可推广至其它二维材料的大尺寸单晶制备，为后续二维量子器件的研究奠定了坚实的材料基础。

I. Growth of Decimeter-sized Single-crystal Hexagonal Boron Nitride on Surface-symmetry broken Substrate

In past decades, with the continuous reduction of key component size in chips, the problems such as short-channel effects, thermal effects, etc. in traditional silicon-based semiconductor devices have taken place and obstructed the further development. The research and development of brand-new two-dimensional (2D) quantum materials to achieve the devices for revolutionary applications has been of the cutting-edge and popular direction. High-integration 2D devices require large-size, high-quality single-crystal 2D materials, thus the preparation of single-crystal 2D materials has been of the greatly scientific significance and technical value. In 2017, a research team led by Academician Enge Wang, Academician Dapeng Yu, and Professor Kaihui Liu from School of Physics in Peking University prepared a meter-scale single-crystal graphene on a single-crystal Cu (111) substrate through epitaxial growth (Xiaozhi Xu et al, Science Bulletin 62, 1074 (2017)). However, unlike graphene, most two-dimensional materials, such as hexagonal boron nitride, do not have the lattice of central inversion symmetry, thereby numerous twin grain boundary would be commonly generated during the epitaxial growth via regular approach. Therefore, exploring a new growth mechanism to realize the preparation of wafer-level single-crystal 2D material without central inversion symmetry is very important and also very challenging.

The key to solve this problem is to control the symmetry of substrate by well design. The research team led by Academician Enge Wang, Academician Dapeng Yu, and Professor Kaihui Liu from School of Physics in Peking University has found a new method of growing the single-crystal 2D material without central inversion symmetry on the surface-symmetry broken substrate, by which the decimeter-sized single-

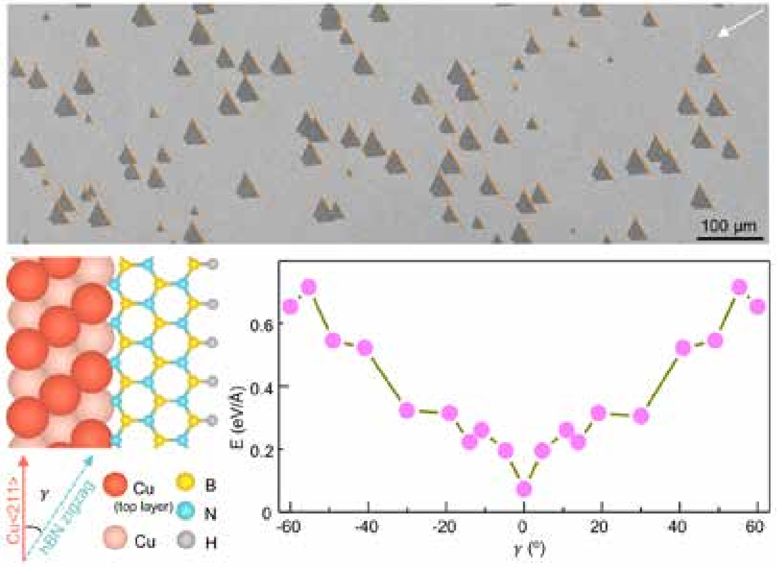


图 1. 分米级单晶六方氮化硼单层薄膜的生长及生长动力学研究

Figure 1. Growth and relative kinetical research of decimeter-sized single-crystal hBN single layer.

crystal hexagonal boron nitride (hBN) was prepared accordingly. This work has been published in Nature with the title of “Epitaxial growth of a 100-square-centimetre single-crystal hexagonal boron nitride monolayer on copper” (Li Wang et al, Nature 570, 91 (2019)). By using a patented method, industrial polycrystalline copper foil could be annealed into the single-crystal Cu(110) with a vicinal surface of just C1 symmetry, and consequently break the equivalence of lattice orientation for hBN domains with rotation angle of 180° through the different formation energy of the coupling between Cu<211> step-edge and zigzag-edge of hBN domain with different termination (B- or N-), to further realize the seamless stitching of the unidirectionally aligned hBN domains, into a decimeter-sized single crystal (Figure 1). For the first time, this method has proposed a new idea for growing 2D single crystal on the surface-symmetry broken substrate, which can be promoted to the preparation of other 2D single crystals, and pave the way for the subsequent research of 2D quantum devices.

二、稳定的高性能亚 10 nm 二维 Bi_2O_2Se 和碲烯晶体管

硅晶体管已经达到其物理极限。摩尔定律难以靠硅晶体管延续到亚 10 纳米尺寸。二维材料具有原子级平整，厚度超薄，以及无侧向悬挂件的特点，可以实现更高效的门控和电子输运，被视为后硅时代潜在的沟道材料。要取代硅的二维材料需要稳定且具有高载流子迁移率。但这样的二维材料非常罕见。 Bi_2O_2Se 具有超高的迁移率（室温下为 450 $cm^2\ V^{-1}s^{-1}$，低温下能达到 29000 $cm^2\ V^{-1}s^{-1}$），极低的有效质量（$me^*= 0.14m_0$）和高度稳定性这些优质特点。其块材、少层乃至单层易制备。物理学院吕劲课题组基于第一性原理量子输运计算，研究并预测了单层和双层 Bi_2O_2Se 场效应晶体管在亚 10 纳米尺度上的性能表演极限。在获得和评估转移曲线、开关比、亚阈值摆幅、延迟时间等关键参数之后，发现双层 Bi_2O_2Se n 型场效应晶体管能够在门长 5 纳米的情况下满足国际半导体线路图未来十年高表现器件的需求，p 型不能满足高表现器件的要求；而单层 Bi_2O_2Se n 型和 p 型场效应晶体管则分别在门长 2 纳米和 3 纳米的情况下仍能满足未来高表现器件的要求。单层和双层 Bi_2O_2Se n 型场效应较 p 型更优异的性能表现得益于其电子比空穴的有效质量小，从而有更快的输运速度。单层较双层更优异的性能是由于单层 Bi_2O_2Se 1.14 eV 的带隙较双层的小带隙（0.18 eV）更适合逻辑器件开关态的切换。与其它单层二维材料（arsenene, antimonene, InSe, black phosphorene, MoS_2）器件的开电流相比，单层 Bi_2O_2Se 晶体管的开电流是稳定二维材料（arsanene, antimonene，MoS_2）中最大的，双层 Bi_2O_2Se 晶体管的开电流虽次于单层的表现，但远远高于 MoS_2 的开电流。综上，理论上讲，二维 Bi_2O_2Se 有望成为延续摩尔定律的沟道材料。相关工作发表在《Nanoscale》11(2), 532-540 (2019) 和《Advanced Electronic Materials》5(3), 1800720 (2019)。其中《Nanoscale》上的工作进入 ESI 高被引论文。

碲烯也具有高载流子迁移率和良好的空气稳定性，也被认为是后硅时代场效应晶体管沟道材料的候选者。吕劲课题组基于第一性原理量子输运计算，首次探索了亚 5 纳米门长的单层碲烯场效应晶体管的器件性能极限。发现 p 型单层碲烯场效应晶体管沿 armchair 和 zigzag 两个方向都可以很好地满足国际半导体技术发展路线图高性能器件的要求，分别可以将摩尔定律延长至门长 4 纳米和 5 纳米，虽然不能满足低功耗器件的性能要求，但引入负电容介电层后有效提升了器件的开电流水平，改善了器件的表现，不仅将 zigzag 方向的高性能极限门长延长至 4 纳米，而且使得 armchair 方向单层碲烯场效应晶体管可以在门长 4 纳米时达到低功率器件的要求。因此，选择单层碲烯作为沟道材料，提供了一种将摩尔定律延续到 4 nm 的新途径。相关工作发表在《Advanced Electronic Materials》，5,1900226 (2019)。

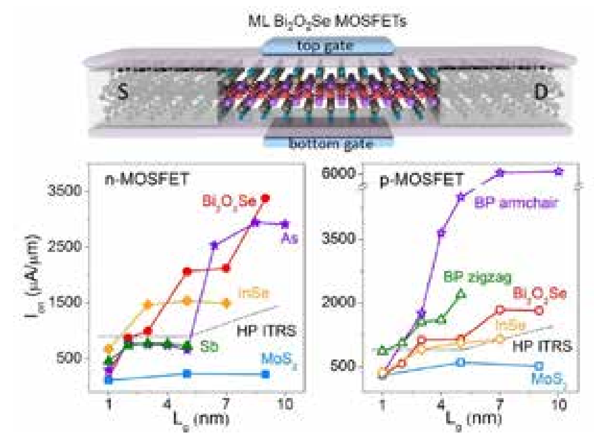


图 1. 单层 Bi_2O_2Se 晶体管示意图与二维晶体管性能比较 .

Figure 1. Schematic view of the monolayer Bi_2O_2Se transistors and comparison of two dimensional semiconductor transistors.

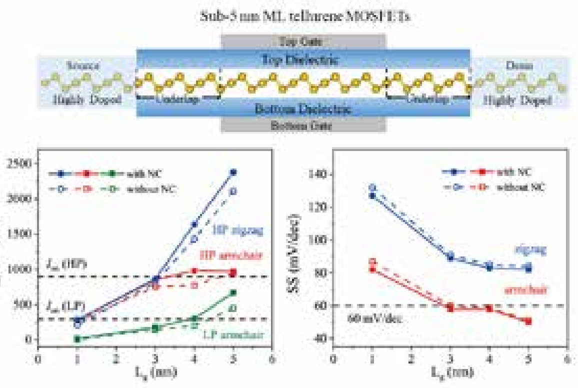


图 2. 单层碲烯晶体管示意图与性能

Figure 2. Schematic view of the monolayer tellurene transistor and the device performance

II. Stable and High-performance Sub-10 nm 2D Bi_2O_2Se and Tellurene Transistors

Silicon transistors have reached their physical limits. Moore's Law is difficult to extend to sub-10 nanometers by silicon transistors. Two-dimensional materials having ultra-thin thickness and uniform surfaces without dangling bonds, enable to achieve more efficient gate control and electronic transport and thus are considered as potential channel materials in the post-silicon era. In order to replace silicon, the two-dimensional materials must first have stability and high carrier mobility. However, such two-dimensional materials are very rare. Bi_2O_2Se has ultra-high mobility (450 $cm^2\ V^{-1}s^{-1}$ at room temperature and 29000 $cm^2\ V^{-1}s^{-1}$ at low temperature), extremely small effective mass ($me^*= 0.14m_0$) and high stability. The bulk Bi_2O_2Se, few layers and even monolayer Bi_2O_2Se are easily fabricated in the experiment. On account of these advantages, Lu Jing et al. predict the performance limits of the sub-10 nm monolayer and bilayer Bi_2O_2Se field effect transistors based on the first-principles quantum transport calculations. After evaluating key figures of merits of transfer characteristics, on-off ratio, subthreshold swing and delay time, we find that the bilayer Bi_2O_2Se n-type field effect transistor can meet the International Technology Roadmap for Semiconductors (ITRS) for the high performance device in the next decades at a gate length of 5 nm while the p-type bilayer transistor cannot meet the high-performance requirements.

The monolayer Bi_2O_2Se n- and p-type field-effect transistors can meet the requirements of future high-performance devices with the gate lengths scaled down to 2 nm and 3 nm, respectively. The monolayer and bilayer Bi_2O_2Se n-type transistors are superior to the p-type counterparts. The reason lies on the fact that the electrons with smaller effective mass than the holes have faster transporting speed. The superior performance of the monolayer Bi_2O_2Se is due to a suitable band gap of 1.14 eV compared with a band gap of 0.18 eV in the bilayer one. The smaller band gap benefits to the switching ability of the logic device. The monolayer Bi_2O_2Se transistor has the largest on-state current compared with other stable two-dimensional materials (arsenene, antimonene and MoS_2). Even though the on-state current of the bilayer Bi_2O_2Se transistor is inferior to that of the monolayer counterpart, it is much higher than that of the MoS_2 transistors. Therefore, two-dimensional Bi_2O_2Se is expected to be a channel material that continues Moore's Law. The related work is published in Nanoscale 11(2), 532-540 (2019) and Advanced Electronic Materials 5(3), 1800720 (2019), and the former is ranked as the ESI high cited paper.

Tellurene also has high carrier mobility and excellent ambient stability and is also considered as a candidate for the post-silicon field effect transistor channel material. Lu Jing et al. explore the device performance limit of the sub-5 nm monolayer tellurene metal-oxide-semiconductor FETs (MOSFETs) by employing exact ab initio quantum transport simulations for the first time. The optimized p-type monolayer tellurene MOSFETs along both the armchair and the zigzag directions can well meet the high performance goals of ITRS at the gate length of 4 and 5 nm, respectively. The introduction of negative capacity dielectric effectively improves the on-state current of the p-type monolayer tellurene MOSFETs and boost the device performance. The p-type monolayer tellurene MOSFETs along zigzag direction can satisfy the high performance requirements of the ITRS at a gate length of 4 nm, and can meet the low power goals along the armchair direction. Hence, choosing monolayer tellurene as the channel material provide a novel route to continue the Moore’s law to 4 nm. The related work is published in Advanced Electronic Materials 5, 1900226 (2019).

三、纳米激光领域研究进展

激光器的研制加深了人们对光与物质相互作用的认识，并极大地推动了现代科学与技术的发展。自激光器发明以来，其微型化一直是激光领域核心的研究方向之一。其目的是获得更小体积、更高调制速度以及更低功耗的激光器。等离激元纳米激光器是一种三维物理尺度可同时远小于出射波长的新型激光器。这种纳米激光器与传统的光学激光器不同，它是通过放大金属中自由电子振荡形成的表面等离激元，而非光子，从而可实现深亚波长 10 纳米量级特征尺度的光场限制。

物理学院马仁敏研究员带领研究组通过系统优化增益材料、金属材料以及共振腔，使纳米激光器激射阈值降低至 10 千瓦每平方厘米水平，比目前已报导的最低的纳米激光器的阈值低两个量级以上。首次将纳米激光器的阈值降至可商业化激光器的激光阈值水平。并进一步系统研究了约 100 余组等离激元纳米激光器与约 100 余组无等离激元效应的对照样品，实验给出了等离激元纳米激光器各关键性能随尺寸变化的规律，证明了等离激元效应可以使激光器同时具有更小的物理尺寸、更快的调制速度、更低的阈值与功耗，并给出了确定的物理机制。工作以“Unusual scaling laws for plasmonic nanolasers beyond the diffraction limit”为标题发表在《自然 - 通讯》上（Nature Communications, 8, 1889, 2017）。

这项工作的意义在于，解决了金属能否提高激光器性能这一纳米光学领域长期悬而未决的问题，为激光的进一步微型化，实现更低功耗、更快速度的纳米激光扫清了障碍。成果入选了“2018 中国光学十大进展”。同时该工作被 Nature Materials 以 News & Views 形式专题报导（Nature Materials, 17, 116–117 (2018), ），文章认为金属等离激元效应能否提高激光器性能是纳米光学领域一个长期悬而未决的问题（a long-standing question debated among the nanophotonics community），马仁敏和同事通过系统深入的实验解决了这一问题（Ren-Min Ma and colleagues address this issue through a thorough experimental study）。并评论申请人等报导的结果很重要，因为他们揭示了等离激元纳米激光器在衍射极限下相较与光学激光器的优势，为激光的进一步微型化铺平了道路（The results reported by Ma and coauthors are of high importance, as they demonstrate the advantage of plasmonic lasers over photonic lasers (of the same sub-diffraction size) and pave the road to their further miniaturization）。

在另一项工作中，马仁敏研究员与合作者采用漏辐射显微成像技术，通过动量匹配的方法将纳米激光器的表面等离激元暗辐射耦合到远场，实现了实空间、动量空间和频谱空间的直接成像。结果表明纳米激光器与传统激光器相比存在本质区别，其辐射场可以全部为金属中自由电子振荡形成的表面等离激元形式。该工作首次揭示纳米激光器的辐射能量可以百分之百耦合到传播模式的表面等离激元，为对纳米激光器进行进一步操控和应用奠定了基础。工作以“Imaging the dark emission of spasers”为标题发表在《科学 - 进展》上（Science Advances, 3, e1601962, 2017）。

III. Research advances in nanolasers

Plasmonic nanolasers are a new class of amplifiers that generate coherent light well below the diffraction barrier bringing fundamentally new capabilities to biochemical sensing, super-resolution imaging, and on-chip optical communication. However, a debate about whether metals can enhance the performance of lasers has persisted due to the unavoidable fact that metallic absorption intrinsically scales with field confinement. Ren-Min Ma et al. reported plasmonic nanolasers with extremely low thresholds on the order of 10 kW cm^2 at room temperature, which are comparable to those found in modern laser diodes. More importantly, Ren-Min Ma et al. found unusual scaling laws allowing plasmonic lasers to be more compact and faster with lower threshold and power consumption than photonic lasers when the cavity size approaches or surpasses the diffraction limit. This clarifies the long-standing debate over the viability of metal confinement and feedback strategies in laser technology and identifies situations where plasmonic lasers can have clear practical advantage. The work is published on Nature Communications with the title of “Unusual Scaling Laws for Plasmonic Lasers beyond Diffraction Limit” (Nature Communications, 8, 1889, 2017).

Nature Materials highlighted this work . In the News & Views article (Nature Materials, 17, 116–117 (2018)), Prof. Mikhail A. Noginov and Prof. Jacob B.

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Khurgin wrote, "A long-standing question debated among the nanophotonics community is whether size matters and helps to reduce the threshold of micrometre- and submicrometre-sized lasers, and whether the presence of metal interfacing the gain medium harms or improves the laser performance. In a work published in Nature Communications, Ren-Min Ma and colleagues address this issue through a thorough experimental study, and conclude that when the device dimensions approach the diffraction limit, plasmonic (metal-based) lasers have superior performance over traditional photonic lasers as they are faster and have lower threshold and lower power consumption.". This work is awarded as "China's Top 10 Breakthroughs in Optics 2018".

In another work, Ren-Min Ma et al. directly imaged surface plasmon emission of spasers in spatial, momentum, and frequency spaces simultaneously. They theoretically showed that spasers could serve as a pure surface plasmon generator with a coupling efficiency to plasmonic modes approaching 100% and we experimentally demonstrated a nanowire spaser with a coupling efficiency of 74%. Our results provide clear evidence of spasing behavior, an intrinsic but unrevealed feature of this intensively studied new class of optical amplifiers. Furthermore, in contrast to the scattered photons, the surface plasmon emission of spasers is a crucial element for various nanophotonic applications. The direct imaging and high generation efficiency of this dark emission will pave the way for various applications of spasers in on-chip nanophotonic circuits, nonlinear nanophotonics, sensing, and imaging. This work is published on Science Advances with the title of "Imaging the dark emission of spasers" (Science Advances, 3, e1601962, 2017).

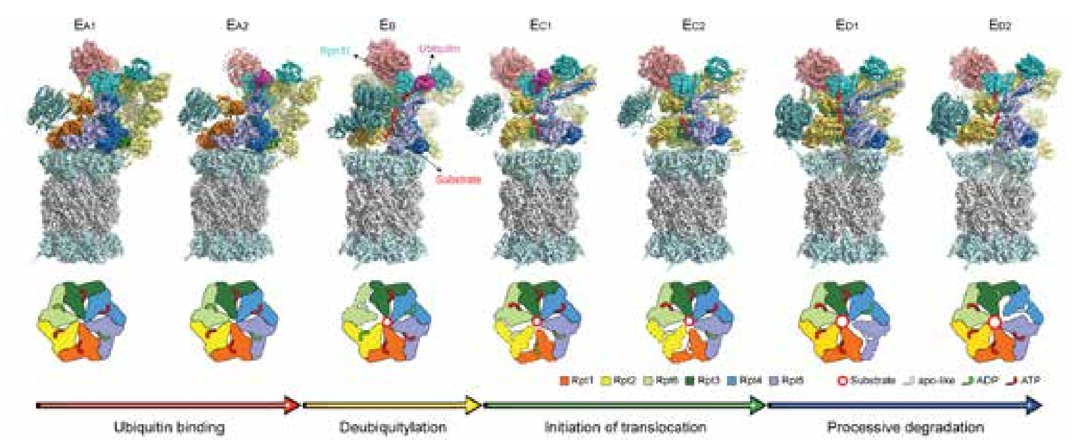
四、软凝聚态和生物物理新突破：揭秘超大型蛋白质复合机器的高分辨动力学

超大型复合蛋白质机器的物理性质和运动行为是当前软凝聚态和生物物理研究的重大前沿课题。超大型复合蛋白质机器是指分子量巨大（1兆道尔顿以上），由几十种蛋白分子通过非公价自组装结合形成的具有类似于马达的化学机械能量转换功能的活性复合物。对于超大型复合蛋白质机器的高分辨物理表征和动态过程的分析曾是“不可能的任务”。然而，超大型复合蛋白质机器对于生命过程的分子实现具有极其重要的决定性作用和功能，例如用于蛋白质合成的核糖体和蛋白质降解的蛋白酶体。

泛素-蛋白酶体体系（Ubiquitin-Proteasome System，简称UPS）是细胞内最重要的蛋白质降解通路，对维持生物体内蛋白质的浓度平衡，以及对调控蛋白、错误折叠或受到损伤的蛋白的快速降解起着至关重要的作用，参与了细胞周期、基因表达调控等多种细胞进程，由UPS失常引发的蛋白质新陈代谢异常与众多人类重大疾病直接相关。人源蛋白酶体全酶包含至少33种不同的亚基，总分子量约为2.5MDa。尽管很多工作揭示了蛋白酶体的基本架构和运动行为[1-3]，但蛋白酶体与底物之间的相互作用从未得到直接的观测，因此蛋白酶体如何作用于底物的复杂动力学过程仍然是理解蛋白酶体生化功能的核心问题。

近日，北京大学物理学院凝聚态研究所、人工微结构和介观物理国家重点实验室、前沿交叉学院定量生物学中心毛有东课题组通过冷冻电子显微镜技术，解析了人源蛋白酶体26S在降解底物过程中的七种化学反应中间态构象的高分辨（2.8~3.6埃）精细原子结构。该课题组利用ATPγS降低AAA-ATPase酶水解活性的特点，在底物降解的中间过程，通过将ATP快速置换成ATPγS，捕捉到蛋白酶体在底物降解过程的反应中间态。同时，他们将机器学习的方法应用到了冷冻电镜图像聚类中，并针对蛋白酶体的动力学特征，整合了多种算法，设计了一套有效的多构象分类流程。通过这两套技术方案的整合，课题组成功解析了人源蛋白酶体在降解底物过程中的蛋白酶体-底物复合体的七种天然中间态构象，在全原子水平展示了蛋白酶体从泛素结合到去泛素化，再到底物转运的动态过程。

该研究工作于2019年1月3日在《自然》（Nature）上以长文（Article）形式正式发表[4]（2018年11月12日首次在线发表）。该工作系统呈现了在原子水平蛋白酶体如何与被降解蛋白底物分子相互作用的动态过程，首次实现了对AAA-ATPase六聚马达分子内ATP水解全周步进循环的完整过程的三维原子水平观测，发现三种不同的ATP水解协同反应模式，并解释了AAA-ATPase将ATP水解化学能转化为机械能实现蛋白底物去折叠的基本物理化学过程，对于理解生物体内蛋白质降解动力学过程和一系列负责物质输运的ATPase分子马达的一般工作原理具有重要的价值。Nature子刊《自然-结构和分子生物学》在News & View栏目对这一工作做了专题亮点介绍和评论[5]。



利用冷冻电镜解析的七个底物结合的人源26S蛋白酶体精细原子结构，揭示了从泛素识别、去泛素化反应、转运启动和持续降价的核心功能动态过程.

Seven cryo-EM structures at atomic-level resolution revealed the inner working of human proteasome and its dynamic substrate-processing steps of ubiquitin recognition, deubiquitylation, translocation initiation and processive substrate degradation. Credit: Shuwen Zhang and Youdong Mao.

IV. Breakthrough in soft matter and biophysics: Decoding dynamics of the largest protein-degrading machine in atomic detail

Protein dynamics are essential for their functions. Protein nanomachines made of multiple protein molecules are highly dynamics during their actions on their functional targets, sometime called substrates. Dynamics of these large protein nanomachines of more than megadalton molecular weight are refractory

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to structural analysis by existing technology like X-ray crystallography and nuclear magnetic resonance spectroscopy. Cryo-electron microscopy (cryo-EM), an emerging technology for high-resolution structure determination, has potential to visualize dynamics of large protein nanomachines, but the existing cryo-EM reconstructions of highly dynamic structures have been limited to moderate to low resolution[1-3]. Scientists have long dreamed of decoding dynamics of large molecular machines of megadalton sizes in atomic detail, the ultimate determinant of their biological functions. Now, a team of biophysicists led by Professor Youdong Mao from the School of Physics at Peking University have used cryo-EM to visualize atomic-level dynamics of the 2.5-megadalton proteasome, the largest known protein-degrading machine in eukaryotic cells, during its chemo-mechanical action on a protein substrate[4]. They reconstructed nearly complete dynamic procedure of substrate processing in the human proteasome at unprecedented resolution that allows determination of atomic details in 3D, much like "filming a 3D movie atom by atom".

Ubiquitin-Proteasome System (UPS) is the most important protein degradation pathway in cells. It maintains the balance of protein materials in living cells, and plays a crucial role in rapid degradation of regulatory proteins, misfolded proteins or damaged proteins. UPS is involved in arguably all cellular processes, such as cell cycle, gene expression regulation and so on. Abnormal protein metabolism caused by UPS disorder is directly related to many human diseases including cancer. In 2004, Aaron Ciechanover, Irwin Rose and Avram Hershko were awarded the Nobel Prize in chemistry, for their discovery of this degradation pathway. At the heart of the UPS is the proteasome responsible for breakdown of ubiquitin-tagged substrates. It is one of the most fundamental, indispensable and complicated gigantic holoenzyme machines in cells. Human proteasome holoenzyme contains at least 33 different kinds of subunits with a total molecular weight of about 2.5-megadalton. It is also known as the direct target of several small-molecule drugs approved by FDA of United States to treat multiple myeloma.

Using cryo-EM in combination with machine learning technology, the team determined dynamic structures of the substrate-engaged human proteasome in seven intermediate conformational states at 2.8-3.6 Å resolution, captured during breakdown of a polyubiquitylated protein. At this resolution, the team was able to identify single magnesium ions bound to both ATP and ADP in the cryo-EM density maps. These 3D structures illuminate a remarkable spatiotemporal continuum of dynamic substrate-proteasome interactions. Intriguingly, the team found that the initiation of substrate translocation is extensively coordinated with other dynamic regulatory events preparing the proteasome for processive substrate degradation. Through further systematic analysis, the team discovered how the chemical energy of ATP hydrolysis is converted into the mechanical work of substrate unfolding through a highly concerted process of multi-protein conformational changes.

Their finding provides novel insights into the complete cycle of substrate processing and suggests distinct modes followed by ATP hydrolysis in the proteasome holoenzyme. It is believed to be the first time that a complete cycle of sequential ATP hydrolysis in an AAA-ATPase heterohexameric motor was visualized at atomic level. This resolves a longstanding scientific debate about ATPase hexamers between two hypothesized models, one suggesting sequential ATP hydrolysis and the other assuming random hydrolytic events in the hexameric ring. Notably, the team observed three principal modes of highly coordinated ATP hydrolysis, featuring hydrolytic events in two oppositely positioned ATPases, in two adjacent ATPases, and in one ATPase at a time. These hydrolytic modes elegantly regulate deubiquitylation, translocation initiation, and processive unfolding of substrates, respectively. This study was published in one of the most prestigious science journals Nature as a research Article4 on January 3, 2019, and has been also highlighted in Nature Structural & Molecular Biology[5].

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03 现代光学研究所 Institute of Modern Optics

北京大学现代光学研究于 1933 年由饶毓泰先生开创，有着悠久的历史和良好的研究基础。2001 年 5 月在北京大学原物理系光学专业的基础上成立了北京大学现代光学研究所，现任所长为龚旗煌院士。北京大学光学学科是"211 工程"、"985 工程"和"双一流"重点建设内容，是国家重点学科和"人工微结构和介观物理国家重点实验室"的主要支撑学科。以现代光学研究所为基地，北京大学还与中科院联合成立了"中科院—北京大学超快光科学和激光物理联合中心"。

现代光学研究所包含光学、原子与分子物理两个二级学科。研究所始终坚持高质量科研队伍建设，拥有国家基金委数理学部光学学科创新群体和科技部重点领域创新团队。通过培养和引进一批优秀青年学者，十多年来研究队伍发展迅速，科研水平逐步提升。截止到 2018 年底，现代光学研究所有固定人员 27 人，其中教授 13 人（含博雅讲席教授 1 人、博雅特聘教授 6 人），博雅青年学者 7 人，"百人计划"研究员 1 人，副教授 2 人，高级工程师 2 人，工程师 2 人。固定人员中包括中科院院士 1 人，长江特聘教授 3 人，国家 973 项目和国家重大研究计划项目首席科学家 2 人，万人计划领军人才 3 人，杰出青年基金获得者 7 人，优秀青年基金获得者 6 人。光学研究所成员在各自领域均已取得非常显著的成绩并得到国内外同行的肯定。多位研究所成员当选美国光学学会（OSA），国际光学工程学会（SPIE）和英国物理学会（IoP） Fellow，担任 Advanced Optical Materials、Optics Letters、Chemical Physics Letters 等国内外重要杂志编委和 Photonics Asia, Nonlinear Optical Phenomena and Applications （SPIE）， Asian Conference on Ultrafast Phenomena 等学术会议主席等职。

系所中心研究亮点 | ***Highlights***

2017-2018 年度，现代光学研究所累计发表 SCI 论文 130 余篇。其中，2017 年肖云峰教授、龚旗煌教授小组发表 Science 学术论文一篇；2018 年朱瑞研究员、龚旗煌教授团队发表 Science 学术论文一篇。同时，2017 年肖云峰教授和龚旗煌院士的研究成果“非对称微腔光场调控新原理研究”入选“中国高等学校十大科技进展”。人才培养方面；2017 年龚旗煌院士当选为中国光学学会第八届理事会理事长、国际光学委员会副主席，2018 年龚旗煌院士当选发展中国家科学院院士，国际光学工程学会（SPIE）会士。此外，2017 年彭良友教授荣获中国物理学会饶毓泰物理奖，李焱教授和杨宏高级工程师获聘为中国光学学会第八届理事会副秘书长；学生培养方面，2017 年黎敏同学获得首届全国光学优秀博士学位论文奖，2018 年韩猛同学获得北京大学五四奖章并担任北京大学学术委员会学生委员。

现代光学研究所以提高创新能力和服务国家重大需求为责任，以建设一流学科为目标。在多年的科研基础上，凝练形成了具有特色和优势的介观光学与纳米光子学、飞秒科学与非线性光学，量子光学与量子信息、强场原子与分子物理、光电功能分子与材料和器件等多个研究方向。在国内外的影响力日益增加，形成了具有国际竞争力的光学和原子与分子物理科研和教学的重要基地。光学学科为学校“双一流”建设做出重要贡献。

The modern optics research at Peking University (PKU) was initiated by Mr. Yutai Rao in 1933. It has a long history and a good research foundation. The Institute of Modern Optics (IMO) was established in May 2001, based on the previous Optics discipline of Department of Physics at PKU. The present director is Professor Qihuang Gong, who is an academician of the Chinese Academy of Sciences and distinguished “Chang Jiang Scholar” of the Ministry of Education of China. The optics discipline at IMO is a National Key Discipline, and is a Key Construction Contents of "211 Project," "985 Project" and “The Double First Class”. 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.

IMO has two secondary disciplines of optics and atomic/molecular physics. IMO always adheres to the construction of a high-quality scientific research team, and has the Optics Discipline Innovation Group of the National Natural Science Foundation and the Key Fields Innovation Team of the Ministry of Science and Technology of China. The research team has developed rapidly in the past ten years through training and introducing a lot of outstanding young scholars. As the end of 2018, IMO has 27 faculty members (including 23 academic faculty members and 4 engineers). There are 13 professors （including 1 Boya Chair Professor, 6 Boya Distinguished Professors）， 7 Boya Young Scholars, 1 “Hundred Talents Program” Scholar，2 Associate Professors, 2 senior engineer and 2 engineers. There are 1 academician of the Chinese Academy of Science, 5 Changjiang Scholars, 2 Chief Scientists of 973 projects, 3 Leading Talents in scientific and technological innovation of Ten thousand people project. 7 faculties won the National Natural Science Foundation of China (NSFC) support for Distinguished Young Scholars and 5 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. One faculty won Beijing Science and Technology New Star. Many faculties have received great achievements and obtained great recognitions in their research fields. One faculty was elected to the American Optical Society (OSA) and the British Physical Society (IoP) Fellow. Many faculty members were elected as editorial committee or vice editor-in-chief of the journals including Advanced Optical Materials, Optics Letters, Advanced Optical Materials, Chemical Physics Letters, and China Series G. Many faculty members were elected as president of the international academic conferences including Photonics Asia, Nonlinear Optical Phenomena and Applications （SPIE）， Asian Conference on Ultrafast Phenomena.

In 2017, Professor Qihuang Gong was elected the chairman of the 8th Council of China Optical Society, and Vice Chairman of International Optical Committee. In 2018, Professor Qihuang Gong was elected the academician of Academy of Sciences of Developing Counties. Research achievements in the project of “Study on new principle of light field control in asymmetric microcavity” carried by Professor Qihuang Gong and Yunfeng Xiao’s groups was elected as “top 10 scientific and technological progress of Chinese University” in 2017. Professor Liangyou Peng won Rao Yutai Physics Award of Chinese Physics Society.

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、飞秒 - 纳米时空分辨光学实验系统

为了更加直观地探究纳微米世界，研究者们正致力于发展高时间 - 空间分辨能力的实验观测技术。由龚旗煌院士负责的“飞秒 - 纳米时空分辨光学实验系统” 国家重大科研仪器研制项目正是围绕这一目标。最近，该重大仪器项目在基于超快光电子显微镜技术实现表面等离激元的多维度探测方面取得重要进展，相关成果发表在《自然通讯》杂志 [Nature Communications 9, 4858 (2018)]。

基于金属纳米结构的局域表面等离激元因其光场极大增强，尺度高度局域，响应灵敏度高等特点，被大量应用于不同领域。但是，其飞秒量级超短的模式寿命大大限制了其实用性。该工作通过多层微纳结构实现了局域表面等离激元和传播表面等离激元的强耦合 (图 1)。数值模拟了耦合动态过程，证明在强耦合下局域表面等离激元模式和传播表面等离激元模式之间的能量交换。光电子显微镜对表面等离激元模式进行了近场直接成像，突破了远场光学衍射极限，并且结合可调激发光源，实现多维度高空间分辨探测。光电子显微镜测量了表面等离激元模式在频域随激发光波长演化过程。同时，结合超快泵浦探测技术，我们研究了表面等离激元模式在频域随时间变化的演化规律。该工作直观并深入揭示了强耦合体系中的能量转换过程，实现了利用失谐量参数来操控局域表面等离激元模式寿命。相较于原局域表面等离模式，通过强耦合作用其模式寿命由 6 飞秒 (10-15 秒) 增长到 10 飞秒。这一研究成果对进一步发展基于表面等离激元的人工光合成、生物传感等应用具有重要的科学价值。

目前国家重大科研仪器研制项目“飞秒 - 纳米时空分辨光学实验系统”的开发研制正在有序推进中，已经取得了一批包括此工作在内的阶段性成果。此外，该时空分辨实验系统其激发光的波长将拓展覆盖范围从极紫外到近红外，并且集成了低能电子显微镜 (图 2)。该实验系统有望在二维材料、光电材料与器件、表面介观物理等研究领域发挥更大的作用。

系所中心研究亮点 | *Highlights*

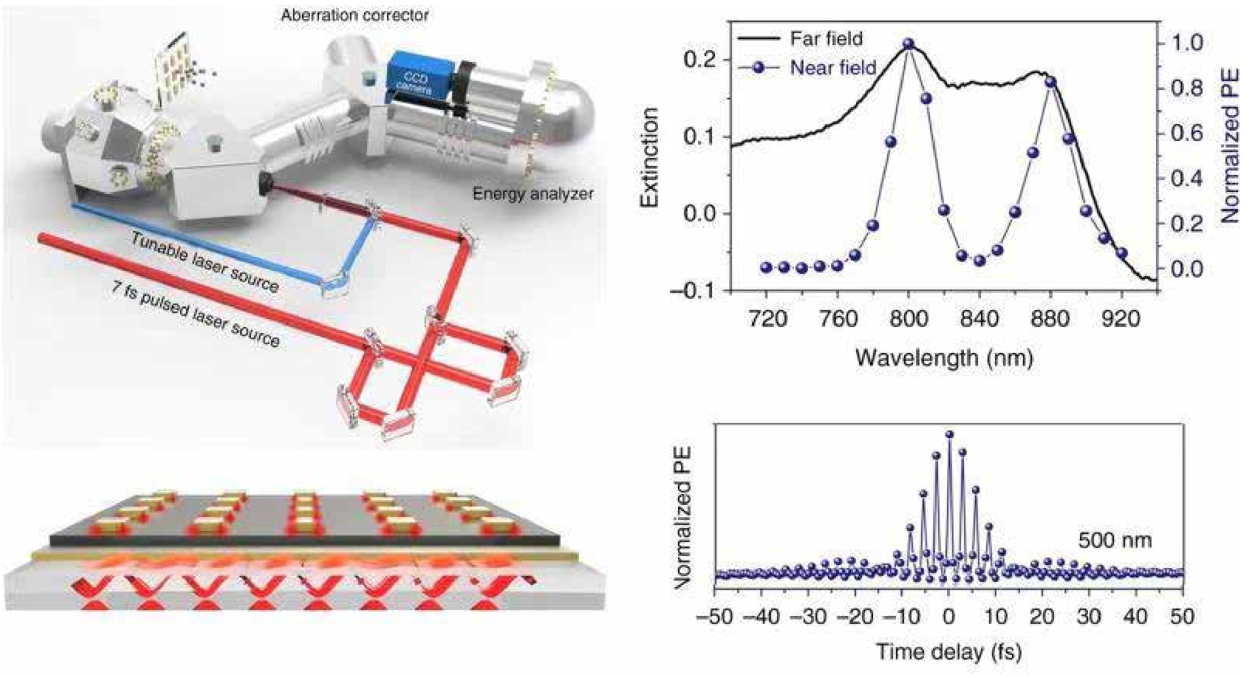


图 1 (a) 光电子显微镜和多层微纳结构示意图，(b) 超快光电子显微镜观测局域表面等离激元模式近场响应曲线和振荡衰减过程。

Fig. 1 (a) PEEM and multi-layer structure schematic diagram. (b) near-field response and deaphsing curves of LSPRs mode recorded by PEEM.

I. Femtosecond Nanometer Temporospatial Resolution System

To investigate the nanoscale phenomena, many researchers have devoted to new experimental technology with high temporospatial resolution. The project "Femtosecond-nanometer Ultrahigh Temporospatial Resolution Optical Experiment System," which is under the leading of Prof. Qihuang Gong, focuses on this goal. It is supported by the program for critical scientific instruments of the National Natural Science Foundation of China. Recently, the project made significant progress in realizing multi-dimensional investigations of surface plasmon modes using ultrafast time-resolved photoemission electron microscopy technology (PEEM).

Localized surface plasmon resonances (LSPRs), the collective oscillation of charge carriers at the surfaces of metallic nanoparticles, can strongly promote the light-matter interactions and confine light on the nanoscale. The most significant properties of LSPRs are their local field enhancement effect and fast damping mechanism, both of which are of great importance in many applications. However, the dephasing time of LSPR modes is usually only several femtoseconds, which limit its applications. The multi-layer nanostructure designed in this work realizes strong coupling between LSPR and surface propagating plasmon (SPP) modes (Fig. 1). The numerical simulation results demonstrate the energy exchange between LSPR and SPP modes. The PEEM directly images the surface plasmon modes at nanometer resolution, overwhelming the optical diffraction limit. Combined with a tunable laser source, the intensity evolution of surface plasmon modes was investigated with PEEM in the frequency domain (Fig. 1). With the help of the ultrafast pump-probe technique, the evolution of surface plasmon modes was recorded by the PEEM in the temporal domain. This work demonstrated the energy conversion process in the plasmonic strong coupling system and controlling on the dephasing time of LSPRs modes through detuning between the plasmon modes. Compared with uncoupled LSPRs, the dephasing time of the strong coupling modes increased from 6 femtoseconds (10-15 seconds) to 10 femtoseconds. This research result has the potentials for the further development of artificial light synthesis and biosensor applications based on surface plasmon polaritons. These results were published in Nature Communications [Nat. Comm. 9, 4858 (2018)].

By the end of 2018, the instrument development and scientific research of the project progress well. The project team will expand the tunable excitation sources ranging from extreme ultraviolet to near-infrared for high temporospatial resolution. They will also integrate the instrument with low energy electron microscopy into the system (Fig 2). This system is a powerful experimental platform for researches in 2D materials, photoelectric materials, and mesoscopic surface physics, etc.

图 2 北京大学研究团队的飞秒纳米时空分辨系统。

Fig. 2 The femtosecond nanometer temporospatial resolution system in Peking University.

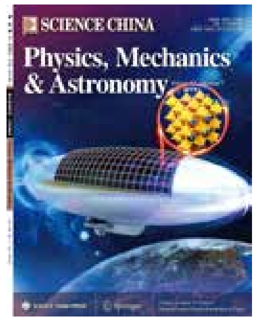
二、钙钛矿太阳能电池

太阳能的利用是当前物理、能源、材料等学科交叉研究的前沿热点。近年来，基于有金属卤化物钙钛矿材料的新型太阳能电池迅速崛起，其光电转换效率在短短十年内实现了跳跃式增长，目前经过认证的效率已经超过 25%，引起了学术界和工业界的广泛关注。

北京大学人工微结构和介观物理国家重点实验室成员朱瑞研究员和龚旗煌院士等人的研究团队在已有的工作基础上，针对反式结构钙钛矿太阳能电池开路电压较低、非辐射复合严重等问题，与英国牛津大学、萨里大学、剑桥大学的合作者开展合作研究，取得了突破性的进展。团队提出了“胍溴化物辅助的二次生长”方法，开创性的实现了钙钛矿薄膜半导体特性的调控，显著降低了器件中的非辐射复合损失，首次在反式钙钛矿太阳能电池中获得了超过 1.21 V 的高开路电压（材料带隙宽度 ~1.6 eV）。因此，在不损失光电流与填充因子的情况下，显著提高了反式钙钛矿太阳能电池的光电转换效率，实验室最高效率达到了 21.5%，第三方机构认证效率为 20.9%，是反式结构器件当时的最高性能。该研究成果发表在《科学》杂志上（Science, 2018, 360, 1442.）。该工作为提升反式钙钛矿太阳能电池转换效率、推进该类新型光伏器件的应用提供了新思路，并对后续相关高性能钙钛矿太阳能电池的研究产生了重要的推动作用。

此外，研究团队也与中科院、西北工业大学等单位开展合作，率先开展钙钛矿太阳能电池在临近空间的应用研究，首次对混合阳离子型钙钛矿太阳能电池在距地约 30 km 的临近空间环境下的工作稳定性问题展开了探索性研究。研究表明基于三元混合阳离子钙钛矿（FA0.81MA0.10Cs0.04PbI2.55Br0.40）的器件在临近空间 AM0 太阳光辐照条件下照射数小时后依然能够维持其初始效率 95% 以上的效率。相关结果发表在《中国科学：物理 力学 天文学》上（Science China-Physics, Mechanics & Astronomy, 2019, 62, 974221），并被选为期刊封面。这一研究是钙钛矿太阳能电池在空间应用领域向前迈出的实质性第一步，具有里程碑式的意义，必将推动该类电池技术在空间飞行器领域的应用。

该系列工作得到国家科技部、自然科学基金委、北京大学人工微结构和介观物理国家重点实验室、“极端光学协同创新中心”、“2011 计划”量子物质科学协同创新中心等单位的支持。



图：a) 团队在提升反式钙钛矿太阳能电池开路电压方面的工作发表在《科学》杂志上。b) 团队在国际上率先开展钙钛矿太阳能电池在临近空间的应用研究，研究结果以封面论文发表在《中国科学：物理 力学 天文学》。

Figure a) Research on the high performance inverted planar perovskite solar cells has been published by Science. b) The group has pioneered the research about the application of perovskite solar cells in the near space. The results were published by Science China-Physics, Mechanics & Astronomy as journal cover.

II. Perovskite Solar Cells

The solar energy utilization is the frontier of multidisciplinary fields, including physics, energy, and material science, etc. Recently, solar cells based on metal halide perovskites have attracted tremendous attention in both the academy and industry. A sharp increase in power conversion efficiencies (PCEs) for perovskite solar cells have been achieved in the past ten years. The best current record efficiency above 25% is comparable to those of single-crystal silicon solar cells.

Prof. Rui Zhu and CAS Academician Prof. Qihuang Gong cooperated with the researchers from University of Oxford, University of Surrey and University of Cambridge, have carried out intensive research in reducing open-circuit voltages (Voc) deficits and non-radiative recombination losses of the inverted perovskite solar cells, and have achieved significant progresses. They developed a "Guanidinium-bromide solution-processed secondary growth" (SSG) technique to increase the Voc and further improve device efficiencies. After the SSG process, they demonstrated that the semiconductor nature of perovskites was modified, and non-radiative recombination losses were significantly reduced. For the first time, they have realized a high Voc of 1.21 V in inverted planar perovskite solar cells without compromising a short-circuit current density and a fill factor, resulting in a PCE of up to 21.5% (in laboratory). Meanwhile, they got a record certified efficiency of 20.9% from the recognized third-party organization for inverted planar perovskite solar cells. These results have been published on Science (2018, 360, 1442.). This work provided guidance for the further development of the inverted perovskite solar cells and their industry applications. In addition, insights into this work gained must have resulted great impacts on the following researches associated with high-performance perovskite solar cells.

In addition, under the collaboration with Chinese Academy of Sciences and Northwestern Polytechnical University, this research group has also pioneered the research about the application of perovskite solar cells in the near space, exploring the stability of the mixed-cations perovskite solar cells in the near space environment. For the first time, they demonstrated that the device based on FA0.81MA0.10Cs0.04PbI2.55Br0.40 can retain 95% of its initial power conversion efficiency during the test under AM0 illumination for 2 hours in the near space area (~30 km above the earth surface). This work has been published on Science China-Physics, Mechanics & Astronomy (2019, 62, 974221), and been selected as the cover story by the journal. This work is the first substantive step for perovskite solar cells toward the space application and represents a significant milestone in the perovskite field. This major breakthrough will also promote the future application of perovskite solar cells in the spacecraft.

These research projects are supported by the 973 Program of China, NFSC, MOST, Peking University, State Key Laboratory for Artificial Microstructure and Mesoscopic Physics, Collaborative Innovation Center of Extreme Optics and 2011 Project.

三、极端光学团队在“强激光场下原子隧道电离波包相位”方面的研究进展

量子遂穿是量子力学基本问题之一，通过对量子隧穿电流的测量，可以实现原子尺度的表面成像，是隧道扫描显微镜的基本原理。但如何描述和测量电子在势垒下动力学行为一直未得到深入研究，在原子波函数层次上，开展量子遂穿的实验研究一直是比较困难的。在飞秒强激光和原子分子相互作用的过程中，激光场会将原子内部的库伦场压低，形成了处于基态电子可以发生隧穿的势垒，，即隧道电离。自前苏联科学家 L.V. Keldysh 首次理论上研究以来，一直备受关注，因为隧道电离是强场原子分子光物理以及阿秒物理的重要基石。然而目前的实验和理论一般都只关注于电子隧穿几率，以及电子波包的振幅信息，完全忽略其初始相位，主要是势垒下相位（sub-barrier phase）。势垒下相位携带着光电子丰富的隧穿动力学信息，却至今仍然未被观测到。

刘运全教授研究组针对强激光场作用下原子的遂穿过程开展深入研究，利用等强度的偏振正交的双色飞秒光场（800nm + 400nm），深入研究遂穿电子干涉的干涉动力学。他们提出了利用新型的“时空电子干涉仪”（图 1），探测电子在遂穿过程中获得势垒下相位，揭示电子隧穿的动力学信息。该工作利用先进的冷靶反冲离子电子动量成像谱仪（所谓 COLTRIMS），清晰地测量了正交双色光场下的光子周期内干涉图案（图 2）。通过与理论模拟的对比 [强场近似（SFA），库伦修正的强场近似 (CCSFA) 和全量子计算（数值求解含时薛定谔方程 ,TDSE）]，揭示出了光电子势垒下相位的对干涉图案的贡献，研究表明势垒下相位蕴藏着的电子隧穿动力学信息，对光电子干涉和光电子全息起着不可或缺的作用，该研究工作发表在近期《物理评论快报》上 Phys. Rev. Lett. 119, 073201(2017）。

III. Research progress of the team of extreme light in probing the phase of tunneling wavepackets of atoms in strong laser fields

Phase of microscopic particles is key to interpret their wave-like properties. In strong-field community, coherence transfer (tunneling and re-collision) is the footstone of numerous phenomena, strongly involving with the photoelectron phase. Electron tunneling through an oscillating potential barrier and traveling in the continuum will leave the fingerprints not only on the amplitude of the electron wave-packet (WP), but also on its phase distribution. Previous experiments mainly focus on the ionization amplitude or photoelectron momentum distributions, and the photoelectron phase is less studied. Especially for the accumulated phase through the Coulomb barrier, it has its contribution to the interference patterns on photoelectron momentum distributions and is hard to be observed. Most of classical or semi-classical models, have ignored the subbarrier phase. However, more “quantum” theories pointed that the action of electron penetrating a laser-induced potential barrier is a complex number, where its real part is the so-called sub-barrier phase. The crucial question is, how it can be revealed through a reliable experimental scheme. The research team leaded by Prof. Yunquan Liu have investigated the phase distribution of electron wave packets from strong-field tunneling ionization of atoms. They have measured photoelectron momentum distributions of Ar atoms in orthogonally polarized two-color laser fields with comparable intensities. The synthesized laser field was used to manipulate the oscillating tunneling barrier and the subsequent motion of electrons onto two spatial dimensions. The subcycle structures associated with the temporal double-slit interference are spatially separated and enhanced. They used such a spatiotemporal interferometer to reveal sub-barrier phase of strong-field tunneling ionization. This study shows that the tunneling process transfers the initial phase onto momentum distribution. Their work has the implication that the sub-barrier phase plays an indispensable role in photoelectron interference processes. The title of this work entitled with “Revealing the sub-barrier phase using a spatiotemporal interferometer with orthogonal two-color laser fields of comparable intensity” was published on Phys. Rev. Lett. 119, 073201(2017）。

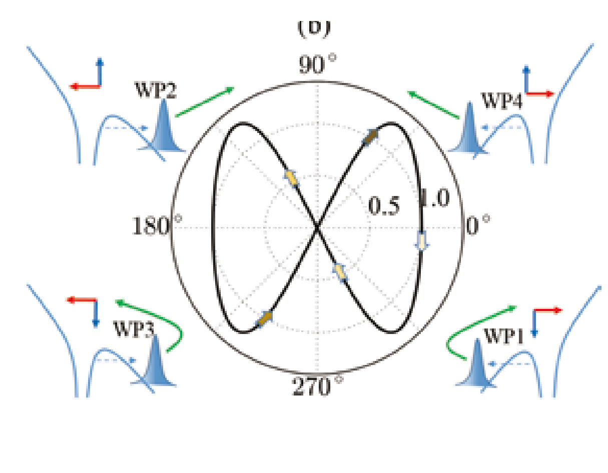


图 1 等强度偏振正交的 800nm 和 400nm 激光的合成光场的时空结构以及在激光场最大值处的量子遂穿示意图

Fig.1, The spatial view of the OTC field in the polarization plane (horizontal direction is the x axis and vertical direction is the z axis). In (b) the black line depicts the track of the endpoint of the synthesized electric-field vector in one 800 nm cycle (the radial coordinate represents the electric-field strength and the angular coordinate means its direction), and the yellow arrows on the black line mark the increase of time as the color gradually deepens.

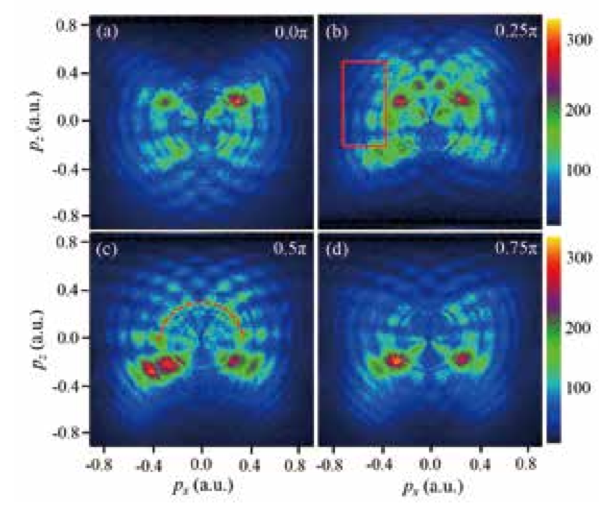


图 2 实验上测量到的在不同相位的 0 π (a), 0.25 π (b), 0.5 π (c), 0.75 π (d). 正交双色光场中光电子干涉图样

Fig 2. Experimental photoelectron momentum distributions of Argon in an OTC field in the polarization plane for (a), 0.25 π (b), 0.5 π (c), 0.75 π (d).

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

北京大学核科学前身为物理教研室，是新中国第一个核学科培养基地，60 多年来培养了大量的高级专业人才（其中包括 15 位两院院士）。重离子物理研究所目前是该学科的依托单位，它根据自身特点同时面向科学前沿和国家重大需求，不断调整学科方向，开展高水平前沿研究，同时完善研究生课程设置，优化研究生培养方案。北京大学重离子物理研究所目前拥有核技术及应用、医学物理与工程、等离子体物理、高能量密度物理和先进加速器系统（专业硕士）五个学科培养方向。重离子物理研究所目前拥有一支高水平的科学研究和工程技术队伍，历年来研究所有多名学术带头人在国际和国内学术组织中担任各种职务，多人在大型国际学术会议上做特邀报告，在国内外学术界具有重要的影响力。目前研究所有在职人员 46 人，其中中科院院士 2 人（陈佳洱、张维研（双聘）），国家海外高水平学者 4 人、国家杰出青年基金获得者 2 人，北京大学百人计划研究员 6 人，教授 12 人，副教授（含高工）15 人，博士生导师 27 人。

The discipline of nuclear science and technology at Peking University has been grown up from the Physical Laboratory which was founded in 1955 (Renamed to Department of Technical physics later). In past several decades, more than ten thousands talents have been cultivated including 15 academicians. It insists developing science and engineering simultaneously, developing interdisciplinary and serving to the national vital demand for a long time and has become an important unit for research and talent cultivation of nuclear science and technology in China. Institute of Heavy Ion Physics has established a high-level faculty team with reasonable age structure. There are 46 staff members, in which here are 2 academician of Chinese Academy of Sciences, 4 scholar of "high level Experts overseas", 6 outstanding young scientists of "Hundred young talents plan of Peking University", 12 professors and 27 doctoral supervisors.

一、1% 能散激光离子加速器建成出束

在前期理论和实验研究的基础上，核物理与核技术国家重点实验室 2012 年成功地获得了国家科技部重大仪器专项的支持。需要攻克高对比度与高光强激光技术、自支撑纳米薄膜靶制备技术、超高流强离子束传输技术和激光加速器辐照研究平台等关键技术，最终建成世界上首台超小型激光离子加速器（如图所示），加速参数指标为 1～15MeV 质子束，流强 >108 个粒子 / 发。2017 年 3 月该激光加速器装置建成，出束之后进行了专家现场技术测试。实验中利用能谱仪、RCF 和 CR39，确认加速产生了能量 3-15 MeV 质子束。利用 1um 的塑料靶体，RCF 胶片和 CR39 的探测结果。同时可以看到，激光加速的质子束总电量超过了 300 pC。在加速稳定性测试实验中，进行了 5 发连打测试，并利用汤姆逊谱仪对其进行了探测。5 发的截止能量分别为 12.24 MeV，12.11 MeV，11.42 MeV，12.10 MeV 和 12.07 MeV，显示质子截止能量的稳定性好于 3%。激光加速直接产生的质子束通常具有较大的能散，束流能量和流强的稳定性和可靠性可以通过基于电磁铁束流传输系统进一步改进，从而提供日常运行所需要的可靠性、稳定性和重复性。北京大学首次采用了基于电四极透镜和分析磁铁等高流强离子束流传输和分析系统，并开展了 3-10MeV 能量可调的高流强、短脉冲质子束传输测试，稳定地获得了 1% 能散 / 1-10pC 电量的质子束。上述结果表明，该装置可以像常规加速器一样稳定可靠地运行，用于温稠密产生、核医学、空间辐射环境模拟、惯性约束聚变、国际热核聚变堆等领域的应用研究。

2018 年 5 月 2 日，中共中央总书记、国家主席、中央军委主席习近平来到北京大学考察。习近平在北京大学并听取了课题组关于自主研发的国际首台激光质子肿瘤加速器系统的汇报。习主席指出，科学研究一定要面向国家重点需求，一定要面向国家战略需求，并围绕这两个需求开展前沿基础研究，并尽快实现科技成果转化。

图 2 习近平主席在北京大学并听取了颜学庆团队工作汇报

Fig.2 Report of Yan Xueqing's team in Peking University

图 1 激光离子加速器系统照片

Fig.1 The photo of compact laser proton accelerator (CLAPA)

I. Demonstration of laser proton accelerator of 1% energy spread with accurate beam control through a magnetic lattice

A Compact LAser Plasma Accelerator (CLAPA) that can stably produce and transport less than 10 MeV proton ions with <1% energy spread, several to tens of pC charge is demonstrated. The high current proton beam with continuous energy spectrum and a large divergence angle is generated by using a high contrast laser and micron thickness targets, later it is collected, analyzed and refocused by the electromagnetic lattice using combination of quadrupole and bending electromagnets. This is the first experiment that combines the laser acceleration with a fully functional beam line, realizing the precise manipulation of the proton beams with reliability, availability, maintainability and inspectability (RAMI). It eliminates the inherent defects of the laser driven beams, and prepares the way for the applications of this new generation accelerator, such as medical physics and irradiation physics. It indeed raises the concept of laser acceleration first invented by Tajima and Dawson since 1979 to a real laser proton accelerator by means of magnet lattice control.

二、阿秒 X 射线自由电子激光研究

自由电子激光（FEL）是一种具有广泛用途的相干光源，波长可覆盖太赫兹至硬 X 射线波段。X 射线自由电子激光（XFEL）装置采用大型射频直线加速器将电子能量加速至 10 GeV 左右，并通过色散结构压缩电子束团，压缩后的电子束团在波荡器的周期性磁场中作扭摆运动从而辐射出 X 射线。X 射线脉冲长度一般由电子束团长度决定，此前 XFEL 的最短脉冲长度为几个飞秒。

射频超导与自由电子激光课题组黄森林副教授和 SLAC 国家加速器实验室及劳伦斯伯克利国家实验室（LBNL）的同事共同提出了获得更短脉冲的非线性束团压缩方案。在该方案中，电子束团在时间－能量的相空间内形成角状分布，具有强而窄的电流尖峰和较长的低电流拖尾，只有尖峰部分有足够的强度产生自由电子激光，从而可获得几百阿秒的 X 射线脉冲。该方案已在直线加速器相干光源（LCLS）的实验中成功实现，通过优化加速器参数及电子束团电荷量，首次产生了 200 阿秒、光子能量为 5.6 千电子伏和 9 千电子伏的 X 射线激光脉冲。这一工作已作为亮点文章发表在《物理评论快报》上 [S. Huang et al., Physical Review Letters 119,154801 (2017)]，同时被 Physics 的编辑选为特别关注并以“Attosecond X-ray Flashes”为题进行了报道。

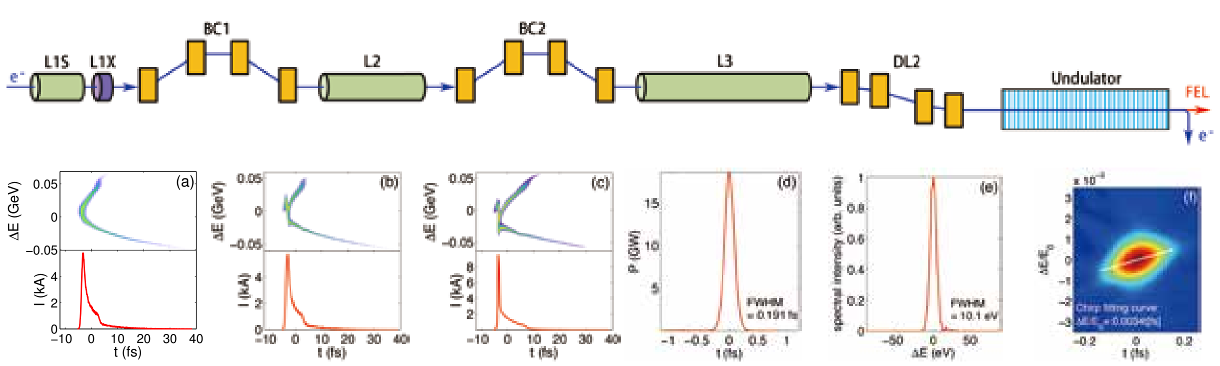


图 1 基于非线性束团压缩方案产生阿秒 X 射线自由电子激光。上图为 LCLS 装置布局图，由主加速段（S 波段直线加速器 L1S、L2、L3），谐波加速段（X 波段直线加速器 L1X），束团压缩结构（BC1、BC2）、DL2 束流传输段、波荡器等组成。下图 (a-c) 依次为 BC2 出口、L3 出口、波荡器入口处的电子束纵向相图和电流分布，(d-f) 依次为模拟计算得到的 FEL 脉冲时间结构、功率谱和 FEL 电场的 Wigner 变换。

FIG. 1. A sketch of nonlinear bunch compression at the LCLS. At the top is a layout of the LCLS, with main linac S-band sections (L1S, L2, L3), one X-band linac section (L1X), two bunch compressor chicanes (BC1 and BC2), a dog-leg beam line (DL2), and an undulator. The bottom plots show simulated longitudinal phase space and current profile after BC2 (a), L3 exit (b), and undulator entrance (c), and FEL simulation results, including power profile (d), spectrum (e) and Wigner transformation of the FEL field (f).

II. Research on attosecond x-ray free-electron laser

Free-electron lasers (FELs), which cover the whole spectral regime between THz and hard x-ray, are coherent light source with a wide range of applications. In typical x-ray free-electron laser (XFEL) facilities, the electron bunches are accelerated by large-scale radio-frequency (rf) linacs to ~10 GeV and compressed by dispersive magnetic optics. The electron bunches then wiggle through the periodic field of undulator magnets and emit x-ray radiation, whose pulse duration is above femtosecond level, typically determined by the electron bunch length.

In collaboration with scientists from SLAC National Accelerator Laboratory and Laurence Berkeley National Lab (LBNL), Dr. Senlin Huang, an associate professor from the SRF & FEL group, proposed a simple scheme that leverages existing x-ray FEL hardware to produce stable attosecond x-ray pulses. In this scheme, a horn-shaped electron distribution in the longitudinal phase space is formed before the undulator as a result of nonlinear bunch compression. The electron current profile has a high-current leading peak together with a low-current tail, and the x-ray lasing is well confined within the current peak. This scheme has been demonstrated at Linac Coherent Light Source (LCLS) in the hard x-ray regime at 5.6 and 9 keV, respectively. Single-spike x-ray pulses were obtained with a FWHM duration less than 200 attoseconds and power of 10s GW for the first time. This work was published in Phys. Rev. Lett. [S. Huang et al., Physical Review Letters 119,154801 (2017)] as an editor-suggested highlight paper, and was also highlighted by Physics as an editor-written synopsis with the title “Attosecond X-ray Flashes”.

三、动态电离致稳激光光压离子加速

强激光与物质相互作用过程中，产生的加速电场可达 100 GV/m 以上，比传统射频加速器高 3 个数量级，能够在厘米量级的距离内将带电粒子加速到 GeV 能量，因此利用激光加速器取代传统加速器引起了科学界的广泛兴趣。其中，强激光驱动的高品质离子源在聚变能源、医疗、核物理和粒子物理等领域都有重要应用。目前，在诸多激光离子加速机制中，光压加速（Radiation Pressure Acceleration，RPA）理论上获得的离子束具有能散小、束流密度大、能量转化效率高等特点。RPA 理论及一维模拟结果极具吸引力，但目前实验上还难以获得预期的好结果。究其根源，除去实验上激光靶参数不够理想外，最关键的原因就是高维条件下不稳定性的剧烈发展。主流认为主要是类瑞利 - 泰勒（RT-like）不稳定性在起负面影响。这种不稳定性发展最终会引发同步加速等离子体片中电子的加热和大量损失，导致等离子片发生库仑爆炸，加速被破坏，最终获得的离子束品质差。如何抑制不稳定性诱发的破坏影响是目前 RPA 研究最具挑战性的问题之一，诸多方法被提出和研究，但实际效果一直都不理想。

经过数年的深入研究，乔宾课题组，另辟蹊径，按照完全不同的思路，考虑如何动态地弥补光压加速中 RT 等不稳定性带来的破坏作用而非仅仅抑制不稳定性发生这一想法，首次提出利用高 Z 涂层的电离效应在激光光压加速过程中动态补充电子，弥补 RT 不稳定性带来的加速等离子体片的电子损失，从而实现动态致稳 RPA，如图 1（a）所示。

这一全新方案非常“皮实”，三维粒子模拟显示在目前真实的激光和靶参数条件下，此方案可实现稳定的光压离子加速，并且可以应用于加速高 Z 重离子源【图 1（b）和（c）】。相关研究成果于近期发表在 Physical Review Letters 上。PRL 审稿人对该方案给出了高度评价，认为该工作为激光光压加速研究领域做出了重要贡献，揭示了动态电离在强激光与重离子相互作用中的重要意义。

该工作得到了国家自然科学基金委、国家重点研发计划和挑战计划的大力支持。

参考文献：

[1] Achieving Stable Radiation Pressure Acceleration of Heavy Ions via Successive Electron Replenishment from Ionization of a High-Z Material Coating, X.F. Shen, B. Qiao, H. Zhang, S. Kar, C.T. Zhou, H.X. Chang, M. Borghesi, and X.T. He, Phys. Rev. Lett. 118, 204802 (2017).

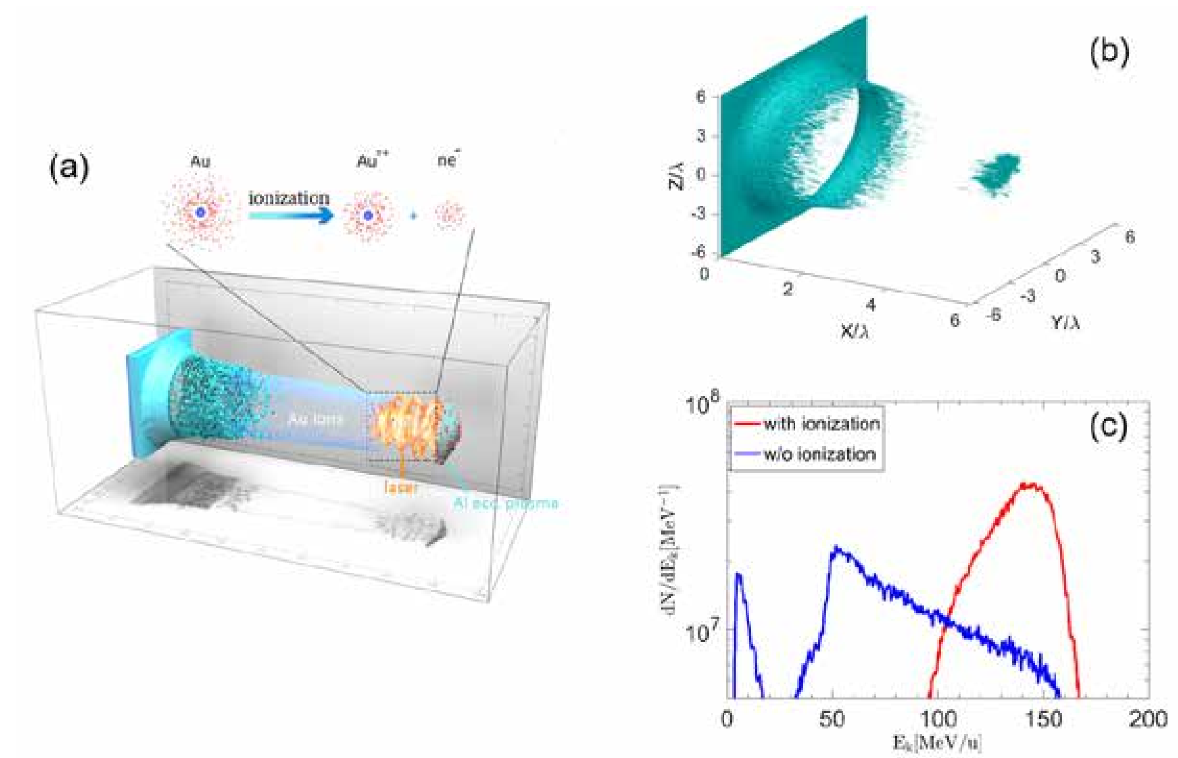


图 1 （a）光压加速动态致稳方案示意图；（b）和（c）分别展示三维粒子模拟结果：（b）带有 Au 涂层的 Al 靶加速后 Al 离子密度分布，（c）考虑（红线）和不考虑（蓝线）动态电离，最终获得 Al 离子能谱。

Fig.1 (a) The schematic of stable heavy ion RPA via successive electron replenishment from ionization of a high-Z coating;(b) and (c) show the 3D-PIC simulation results, respectively:(b) shows the Al^{13+} density isosurface for $n=3n_c$ with the ionization effect at $t=20t_0$; (c) The corresponding final energy spectra of Al^{13+} within with ＜ 2urm(red curve) and without (blue curve) the ionization effect.

系所中心研究亮点 | ***Highlights***

III. Achieving Stable Radiation Pressure Acceleration via Dynamic Ionization

An intense laser-plasma interaction can generate an accelerating field much higher than 100GV/m, which is three orders of magnitude greater than that obtained in conventional radiofrequency linacs. Thus, particle beams with GeV energy level can be obtained in the distances of the order of only centimeters, which induces great interest in using laser-particle accelerator to replace the conventional linacs. Meanwhile, high-quality ion beams driven by intense laser have broad applications in fast ignition, medical therapy, nuclear physics and particle physics. Nowadays, radiation pressure acceleration (RPA) promises high-quality ion beams with smaller energy spread, larger beam current and higher energy convention efficiency, compared with other mechanisms. Though the results of RPA from theory and one-dimensional simulations is very attractive, they are not as good as expected from the present experimental results. Except the imperfect parameters of laser and target used in experiments, the key reason is due to the seriously developing of instabilities in high-dimensional cases, especially for the negative effects induced by Rayleigh-Taylor-like instability. The increase of instabilities eventually leads to serious electron heating and significant amounts of electron losses, which results in Coulomb explosion of the accelerating slab and prematurely termination of ion acceleration. Finally, the obtained ion beams are always characterized with low energy and bad beam quality. Thus, how to suppress the destructive effects induced by instabilities is one of the most challenging problems in the present research of RPA. Though many methods have been proposed, the experimental effects are not satisfied.

After several years of research, Prof. Qiao’s group proposed a novel method considering how to dynamically repair and offset the destructive effects induced by instabilities during acceleration, rather than suppressing the instabilities. Stable RPA is achieved via successive electron replenishment from dynamic ionization of a high-Z material coating, as shown in Fig. 1(a). This method is very robust. Three-dimensional particle-in-cell simulations show that ion stable RPA can be realized even with the real experimental parameters of laser and target, as shown in Fig. 1(b) and (c). More importantly, this mechanism is also suitable for the acceleration of heavy ions. This work was published in Physical Review Letters.

This work was supported by NSAF (Grant No. U1630246); the National Natural Science Foundation of China (Grants No. 11575298 and 11575011); the Science Challenging Project (Grant No. TZ2016005);

Reference:

[1] Achieving Stable Radiation Pressure Acceleration of Heavy Ions via Successive Electron Replenishment from Ionization of a High-Z Material Coating, X.F. Shen, B. Qiao, H. Zhang, S. Kar, C.T. Zhou, H.X. Chang, M. Borghesi, and X.T. He, Phys. Rev. Lett. 118, 204802 (2017).

系所中心研究亮点 | *Highlights*

05 技术物理系 Department of Technical Physics

技术物理系现有教职员工28人，其中：教授8人（其中杰青3人），教授级高级工程师1人，副教授7人，北京大学长聘副教授2人（其中优青1人），预聘助理教授3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。该系拥有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。该系还拥有核技术应用实验室，该实验室拥有包括电弧熔炼、2×1.7 MV串列加速器、透射电子显微镜和X射线衍仪等在内的新型核能材料的制备、辐照、表征和测试平台，主要用于应用核物理研究（核能材料与核技术应用）；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(CUSTIPEN)；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；人才培养方面2008年起与日本理化所合建了Nishina School，2016年与美国MSU建立了由中国留学基金委CSC支持的PKU-FRIB博士后项目等等。

There are 28 faculty members in the department, including 8 full professors(including 3 National Outstanding Young Scientists), 1 professorship engineer, 7 associate professors, 2 tenured Associate Professors (including 1 National Outstanding Junior Young Scientist), 3 tenure-track Assistant Professors (including 2 "National Young QianRen Project" research professor), 1 senior engineer, 1 lecturer and 5 engineers. The research fields cover 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. The department has a subatomic particle detection laboratory, an education laboratory for nuclear physics, and a PKU-Lanzhou joint center for nuclear physics. The department also has nuclear technology application laboratory, which is equipped with critical facilities such as arch melting system, 2×1.7 MV tandem accelerator, transmission electron microscope, X-ray diffractometer for the study of structural materials and ion beam materials. 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), 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. In terms of talent training, an undergraduate education program named the Nishina School has been established with RIKEN in Japan since 2008, and a PKU-FRIB postdoctoral program supported by CSC was established with MSU since 2016.

一、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，北大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子结构技术并应用于如下两项物理研究中。1）引力子及新规范玻色子的寻找。Randall-Sundrum模型和Heavy Vector Triplet模型可用于解释标准模型中存在的hierarchy等疑难，分别预言了高质量的引力子和新的规范玻色子。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，高能实验组利用jet子结构技术开展寻找引力子以及新规范玻色子的研究[JHEP03(2017)162; PLB774(2017)533；JHEP 05(2018)088]。这些工作一方面使得对引力子等新粒子的质量探寻范围扩展到了4.5TeV，另一方面，相关限制也大大增强，比RunI相比相当于严格了8-10倍。2）矢量玻色子散射与反常四规范玻色子耦合的研究。矢量玻色子熔合过程VBF W/Z+γ+2Jets是尚待验证的标准模型预言的物理过程，可以探测WWZγ等四规范玻色子耦合。北大提出并负责了这两个物理分析。利用2012年LHC 8 TeV对撞的20fb-1数据，以近3σ的敏感度首次测量了VBF Zγ+2Jets这个物理过程，并对反常四规范玻色子耦合给出了世界最强的一批限制[PLB 770(2017)380；JHEP06(2017)106]。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。

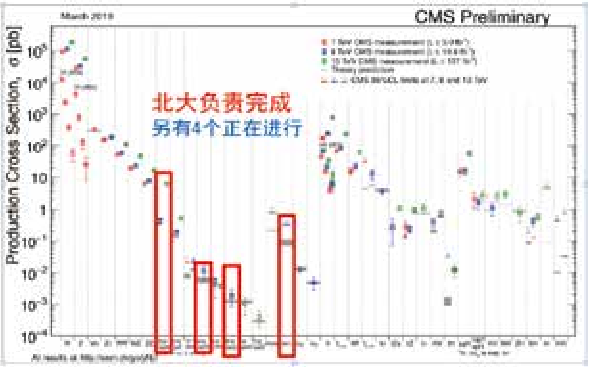


图1、CMS标准模型检验图。图中红色标记的为北大负责完成的四个测量工作，均为世界首次。

Fig.1. Summary plot of SM Measurements at CMS. The red circles include those contributions led by PKU.

I. 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 and applied the jet substructure techniques for boosted W into the following projects. 1) Search for Graviton and extra gauge boson via WW decay .The Randall-Sundrum and Heavy Vector Triplet models predict massive graviton and extra gauge boson. WW final states, here one decays to a fat jet and the other to lepton, could be a good measure for relevant searches. Using jet substructure technique, these results extend the mass range up to 4.5 TeV for the first time, and in the meantime provide the best limit on the production rates, which is 8-10 times better than previous RunI results [JHEP03(2017)162; PLB774(2017)533; JHEP 05(2018)088]. 2) Study on Vector Boson Scattering and Anomalous Quartic Gauge Coupling. The VBS processes, W/Z+γ+2Jets, are predicted by the Standard Model but yet to be discovered. The high energy physics experimental group proposed to measure these two physics processes and led the analyses throughout. Using the 20fb-1 of data of 8TeV proton-proton collision collected by the CMS experiment in 2012, they reached a high observed

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significance at about 3.0 standard deviations for both VBS processes [Fig.1]. They also provided the most stringent constraints on anomalous quartic gauge coupling [PLB 770(2017)380；JHEP06(2017)106].

These works are jointly supported by the Ministry of Science and Technology and National Foundation of Science and Technology.

二、轻丰中子区原子核壳演化

放射性核束物理的发展已将核物理研究逐渐推向了滴线附近。远离β稳定线的丰中子核结构研究一直以来都吸引着研究者们的注意力，其中传统壳的演化受到大家的特别关注。近期，北大实验核物理团队分别利用β衰变和转移反应对Z～10-12，N～20"反转岛"区和N～8轻丰中子区的"壳演化"开展了实验研究。

"反转岛"附近原子核的β衰变实验是在兰州近代物理研究所的RIBLL1终端上开展的。由HIRFL束流线提供的初级束流^{40}Ar入射到^{9}Be靶上产生碎裂，碎裂产物经过RIBLL1束流线分离、纯化，得到Z～12，N～20核区的放射性丰中子次级束。在连续束工作模式下，通过粒子注入探测系统中位置灵敏硅微条探测器和塑料闪烁体的符合关系确认了丰中子衰变母核和β粒子的归属关系以及快时间起始信号，再通过γ探测器和中子探测阵列得到相应的β-γ谱和β-n谱。实验精确测量了"反转岛"附近十余个原子核的半衰期，基于新的半衰期实验结果，研究了"反转岛"区N = 19～22四条同中子素链的半衰期的系统性变化规律（见图1），发现半衰期在Z = 13处出现的系统性"下沉"与Al同位素的结构过渡特点紧密相关，给出了"反转岛"核区北部边界新的实验标志。

N～8轻丰中子区原子核的转移反应实验是在大阪大学核物理研究中心的束流装置上开展的。利用11Be(d, p)^{12}Be转移反应实验，首次定量提取了^{12}Be基态中的s波和d波成分。结果表明（见图2），与^{11}Be的基态中s-wave闯入为主不同，^{12}Be的基态以d-wave闯入为主。虽然^{11,12}Be基态的闯入机制不同，但是研究结果表明传统幻数N=8的主壳被破坏了。

相关研究结果最近已在2篇Physics Letters B文章中报道，该项研究得到了973计划和国家自然科学基金的资助。

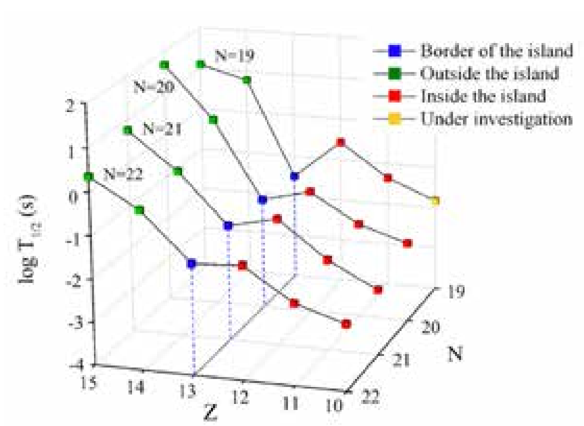


图1："反转岛"附近N = 19　　22四条同中子素链的半衰期变化曲线

Figure 1： Experimental half-lives of four isotonic chains from N=19 to 22 in and around the "island of inversion".

II. Shell evolution in light neutron-rich region

Nuclear studies have been moved forward to the drip line with the development of the modern radioactive ion beam facilities. The research on exotic neutron-rich nuclei far away from the β-stability line has been attractive for nuclear scientists all the time. There are many new interesting phenomena in the neutron-rich region and the "shell breaking" is one of the hottest topics. Recently, the experimental nuclear physics group at PKU has carried out β-decay and transfer reaction experiments to study shell evolution in light neutron-rich region with.

The experiment was carried out at the radioactive ion beam line in Lanzhou (RIBLL). The primary beam 40Ar, which was provided by the heavy ion research facility in Lanzhou (HIRFL), was impinged on a 9Be target to produce the neutron-rich radioactive species around the Z ~ 12, N ~ 20 region. The experiment was performed in the continuous beam mode. By correlating the implantation nuclei with their subsequent β-decays within the same pixel or adjacent pixels of a double-sided silicon detector (DSSD), the β decay properties of implanted nuclei can be measured with much less disturbance from other unstable nuclei and the random background. More than 10 nuclei in and around the "island of inversion" have been investigated and the half-lives of them with higher accuracies have been obtained. With a systematic investigation of half-lives for the isotonic chains from N = 19 to 22 (see Fig. 1), conspicuous kinks observed at Z=13 provide a clear signature of a boundary on the northern (high-Z) side of the island.

The 11Be(d, p)12Be transfer reaction experiment was carried out at the EN-course beam line, RCNP (Research Center for Nuclear Physics), Osaka University. The s-wave spectroscopic factors were extracted for the first 0+ and second 0+ states, respectively, in 12Be. Using the ratio of these spectroscopic factors, together with the previously reported results for the p-wave components, the single-particle component intensities in the bound 0+ states of 12Be were deduced. It is evidenced (see Fig. 2) that the ground-state configuration of 12Be is dominated by the d-wave intruder, exhibiting a dramatic evolution of the intruding mechanism from 11Be to 12Be, with a persistence of the N = 8 magic number broken.

The results were published recently in Journals such as Physics Letters B. This work has been supported by the 973 program and the NSFC projects.

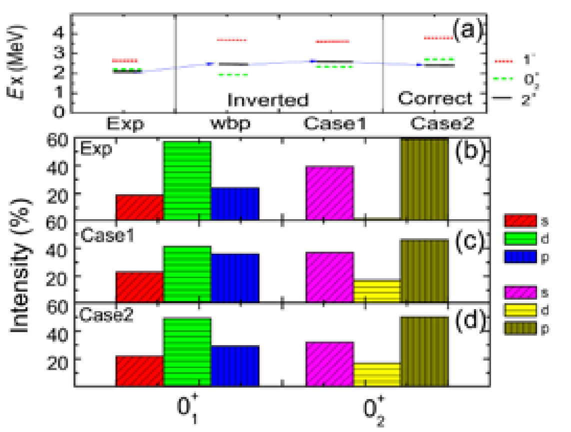


图2:（a）对于12Be低占据态，实验测量和壳模型计算（wbp或者YSOX相互作用）的能级对比图。（b）对于12Be的01+和02+态，实验测量的s-，p-，d-波强度。（c）利用壳模型和YSOX相互作用，计算得到的s-，p-，d-波强度(case1)。（d）同图（c），但是YSOX相互作用中，d-轨道降低了0.5 MeV（case2）。

Figure 2: (a) Comparison of the level schemes of the low-lying states in 12Be between the experimental data and the shell model calculations with traditional wbp or YSOX Hamiltonian. (b) The individual s-, p-and d-wave intensities for the 0+1and 0+2states deduced from experiments. (c) Shell model calculations with YSOX interaction (Case 1). (d) Same as (c) but with a decrease of 0.5 MeV for the d-orbit (Case 2).

三、滴线区原子核的第一性原理计算

滴线区原子核是当前核物理的研究热点。滴线区核具有弱束缚或不束缚特性，实验上很难合成和测量，理论上很难计算，模型应该包含连续谱影响。由于滴线区核的实验数据还非常不充分，所以通常的需要拟合实验数据的唯象模型计算往往不够理想。随着核物理基础理论和计算方法的发展，最近10 余年，核物理第一性原理计算得到很大发展。许甫荣研究团队从手征有效场论出发，发展了滴线区原子核的第一性原理计算，做出了有自己特色的理论工作。

为了包含滴线区连续谱贡献，他们的第一性原理计算是在复动量 Berggren 基矢空间进行的，称为 Gamow 第一性原理计算。在复动量空间进行第一性原理计算是异常困难的，涉及到复杂的数学与数值计算问题。他们成功地发展了两种第一性原理计算：i) 基于现实核力的有芯 Gamow 壳模型和 ii) 基于现实核力的 Gamow 介质相似重整化群。

三体核力是又一个重要前沿热点问题。三体力在描述滴线区原子核中往往起重要作用。他们发展了手征有效场论 N2LO 三体力，并进一步扩展到复动量 Berggren 空间。他们从 CD Bonn 势出发，用 Gamow 壳模型计算了氧同位素的性质（包括激发能谱），重现了滴线核 24O 的弱束缚和不束缚共振特性（见图 1），预言滴线外 ^{25}O 和 ^{26}O 核的共振基态和共振低激发态，文章发表在 Phys. Lett. B 769 (2017) 227.

他们从手征有效场论出发，用 Gamow 介质相似重整化群，计算了中子滴线区碳同位素核的性质，给出滴线核 ^{22}C 的晕性质（见图 2），发现连续谱对描述弱束缚晕结构具有关键作用。预言了 ^{22}C 的低激发态性质，这些预言对目前正在关注的相关实验很有指导价值。

代表性论文：

1.Z.H. Sun, Q. Wu, Z.H. Zhao, B.S. Hu, S.J. Dai, F.R. Xu*, Phys. Lett. B 769 (2017) 227: Resonance and continuum Gamow shell model with realistic nuclear forces.

2.Q. Wu, B. S. Hu, F. R. Xu*, Y. Z. Ma, S. J. Dai, Z. H. Sun, and G. R. Jansen, Chiral NNLOsat descriptions of nuclear multipole resonances within the random-phase approximation, Phys. Rev. C 97, 054306 (2018).

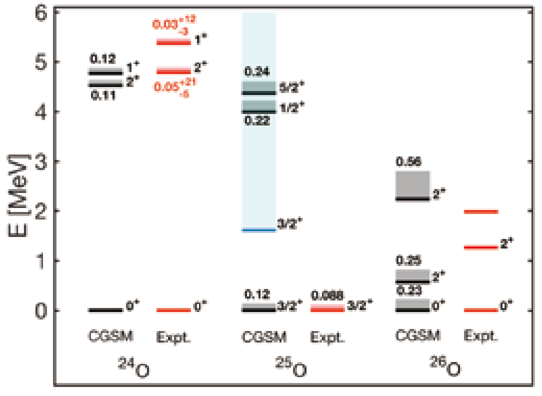


图 1. CD-Bonn Gamow 壳模型计算的链中子滴线区核的激发能谱，给出共振宽度。

Fig.1. Calculated resonant excitation spectra for ^{24}, ^{25}, ^{26}O, using the Gamow shell model with the CD Bonn potential.

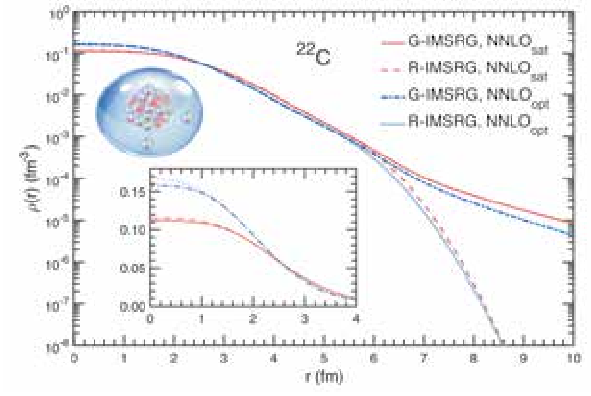


图 2. 手征有效场论 Gamow 介质相似重整化群计算的 ^{22}C 密度分布，给出晕现象。

Fig.2. ^{22}C density distribution calculated with EFT Gamow IM-SRG, giving a halo structure.

III. Ab initio calculations of nuclear structures of dripline nuclei

Nuclei in dripline regions are a frontier of current nuclear physics research. The nuclei have weakly bound or unbound properties. They are difficult to be synthesized and measured experimentally. They are also difficult to be calculated theoretically. Models should contain continuum effects. Since experimental data in dripline region are still very lacking, the usual phenomenological model calculations that need to fit experimental data are often not ideal. With the developments of basic theories and calculation methods of nuclear physics, the first-principles calculations (or called ab initio calculations) of nuclear physics has been greatly developed in the past decade. Starting from the effective field theory (EFT), F. R. Xu's team has developed the first-principles calculations of atomic nuclei and applied to dripline regions.

To include the continuum effect, the first-principles calculation was performed in the complex-momentum Berggren basis, called the Gamow first-principles calculation. It is not a easy task to perform first-principles calculations in the complex-momentum space, which involves complicated mathematical and numerical calculation problems. Nevertheless, Xu's team has successfully developed two types of the first-principles calculations: i) the Gamow shell model based on realistic nuclear forces and ii) the Gamow in-medium similarity renormalization group (Gamow IM-SRG).

Three-body force is another important frontier hot issue. Three-body forces often play an important role in describing the nuclei of dripline regions. They have developed the EFT three-body forces at the level of next-to-next-to-leading order (N2LO), and extended to the complex-momentum Berggren space. Starting from the CD Bonn potential, they have calculated the properties of oxygen isotopes (including excitation energy spectra) using the Gamow shell model. The calculations reproduce well the weakly bound or unbound resonance characteristics of the dripline nucleus ^{24}O (see Figure 1), predicting the resonances of ^{25}O and ^{26}O beyond the dripline. The work has been published in Phys. Lett. B 769 (2017) 227.

With N2LO$_{opt}$ and N2LO$_{sat}$ in which three-nucleon forces are included, they used the Gamow IM-SRG to calculate the properties of carbon isotopes near the neutron dripline, giving the halo property of the dripline nucleus ^{22}C (see Figure 2). It is found that the continuum plays a key role in describing the weakly bound halo structure of ^{22}C. The properties of ^{22}C low-lying states are predicted, which should be useful for relevant experiments that are currently being focused on.

06 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。在 2001 年底教育部组织的全国重点学科评审中，北大天体物理学科被评为全国重点学科。天文学系现有全职教师 10 名，其中教授 5 名， 副教授 4 名，助理教授 1 名。 共有长江学

者特聘教授 1 名，国家杰出青年基金获得者 3 名， 并有兼职中国科学院院士 2 名， 另外还有 10 余名来自国内外高校或科研院所的兼职教授。在站博士后 6 名，博士研究生 73 名，本科生 111 名，办公行政人员 2 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。

The 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. PKU Astronomy was given the status of National Key Discipline by Ministry of Education in 2001. The Department of Astronomy has 10 full-time faculty members consisting of 5 professors , 4 associate professors and 1 assistant professor. Among them, there are 1 Changjiang Scholar chair professor and 3 NSFC “Distinguished Youth Award” winners; besides, Department of Astronomy has over 10 joint faculty members including 2 academicians. Department of Astronomy has 6 post-doctors, 73 post-graduate students, 113 undergraduates and 2 secretaries. 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.

一、发现 20 多个特殊的“变脸”类星体

类星体作为宇宙中发光最强的活动星系核，是研究遥远宇宙的重要探针，其巨大能量来自于中心超大质量黑洞吸积周围物质所释放出的引力能。按照光谱型态的不同，活动星系核一般被分为两类，有宽发射线的 I 型活动星系核和只有窄发射线的 II 型活动星系核。

近几年来，极少数活动星系核光谱中的宽发射线被观测到在几年的时间内会消失，有的在随后几年内甚至又会重新出现宽发射线，这些在短时间内光谱型态发生显著变化的特殊天体被称为“变脸”（changing-look）活动星系核。尽管至今只有 20 多个这样的特殊天体被发现，但它们严重挑战了天文界普遍认可的活动星系核统一模型。按照此模型，I 型活动星系核与 II 型活动星系核主要是由于相对观测者的视线方向不同所致，短期内二者是很难相互转化的。

目前对于这些活动星系核“变脸”的物理机制还存在争议，主要有三种不同的解释。第一种解释是由于大量物质运动而造成的对中心辐射遮挡效应的不同导致的光谱型态变化。第二种解释是这种转变是活动星系核中心超大质量黑洞在不同时期对周围物质的吸积率变化造成的。第三种解释是一颗恒星被超大质量黑洞潮汐瓦解时造成黑洞吸积的状态在宁静和活动之间转换。

近年来，北京大学物理学院天文学系吴学兵教授领导的团队加入到变脸活动星系核的搜寻中，并发现了 21 个红移在 0.08 到 0.58 之间的变脸类星体。其中 10 个是利用我国天文大科学工程郭守敬望远镜（LAMOST）的光谱巡天数据发现的，6 个是利用中国科学院国家天文台兴隆观测站 2.16 米光学望远镜的光谱观测发现的，5 个是利用美国斯隆数字巡天（SDSS）的光谱数据库发现的。这是国际上首次大规模地发现变脸类星体，使得这类天体被发现的数目增加了一倍。研究论文于 2018 年 8 月 1 日在著名天文刊物美国《天体物理学杂志》（Astrophysical Journal）发表，博士研究生杨倩为第一作者。

北京大学团队发现的 21 个变脸类星体的转变

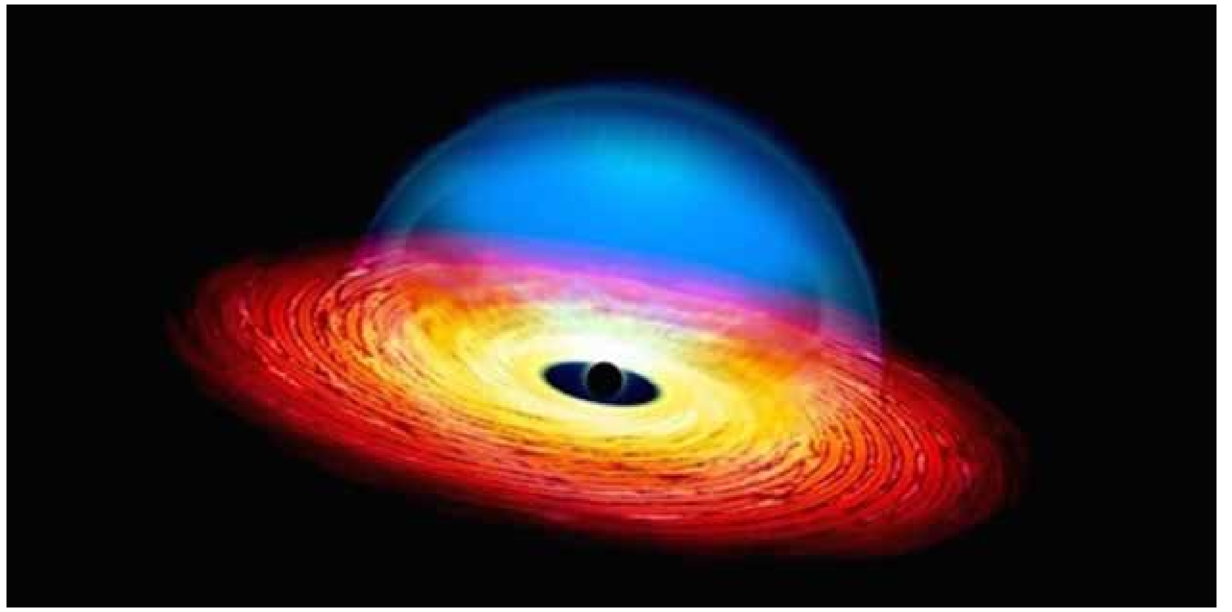


图 1:“变脸”类星体核心区域示意图。中心为超大质量黑洞和吸积盘（图片来源于耶鲁大学 Michael Helfenbein）

Figure 1: The artist's rendering shows the changing look quasar at full brightness (Credit: Michael Helfenbein/ Yale University)

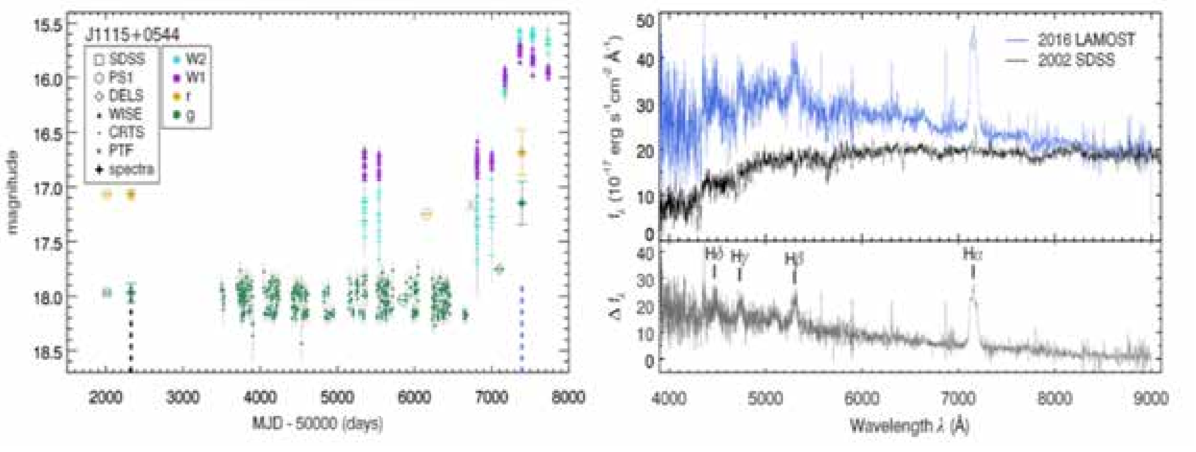


图 2 左图：新发现的变脸类星体 J1115+0544 的光学和中红外波段光变曲线，相同颜色代表同一波段的光变。右图：该变脸类星体间隔十几年的光谱变化。上半部分图中黑色为美国斯隆数字巡天（SDSS）光谱，蓝色为我国郭守敬望远镜（LAMOST）光谱。下半部分给出了两次观测光谱的差异（图片来源于吴学兵团队论文）。

Figure 2: Left: The optical and mid-infrared light curves of a newly discovered changing-look quasar J1115+0544. Right: The spectra change over 14 years. The black and blue curves are SDSS and LAMOST spectra respectively. The lower part shows the difference between two spectra (Figure taken from Yang et al. (2018))

时标约为 1 年到 13 年，证实了在短时间内这些天体的剧烈变化。当这些类星体的活动"开启"(或"熄灭"）时，伴随着连续谱辐射在光学和红外波段的增亮（或变暗）。其中至少 10 个类星体在光学和红外波段的光变幅度与不同的遮挡消光机制（即上面所提第一种解释）有 3σ 置信度以上的不符合。此外，这些源在光学波段的颜色是众所周知的"越亮越蓝"，在中红外波段的颜色却是"越亮越红"。这一观测现象可能是由于当活动星系核的活动变得剧烈时，长波端中红外辐射比短波段中红外辐射会更加明显地受到热尘埃辐射的影响所造成的。

活动星系核变脸的物理机制对于研究活动星系核的演化至关重要。目前，北京大学天文团队正利用国内外望远镜对许多变脸类星体候选体进行光谱观测，有望发现更多的变脸类星体，以促进对这类特殊天体"变脸"物理机制的理解。

论文链接：http://iopscience.iop.org/article/10.3847/1538-4357/aaca3a

I. New Discoveries Double the Number of Changing-look AGNs

Quasars are the most luminous active galactic nuclei (AGN), and are thus very important to probe the distant Universe. Their huge luminosities come from the gravitational energy of accreting matters around the supermassive black holes. According to their spectral properties, AGN can be usually divided into two classes, Type 1 AGN with both broad and narrow emission lines and Type 2 AGN with only narrow emission lines.

Recently, in the spectra of some AGN, the broad emission lines are found to disappear in a few years, and may even re-appear in later years. These rare objects with obvious changes in the spectra within a few years are called "changing-look AGN". Although only about 20 changing-look AGN have been found, they present serious challenges to the widely accepted unification scheme of AGN, which attributes the difference of Type 1 and Type 2 AGN to the different orientations to the dust torus. According to this scheme, Type 1 and Type 2 AGN can not evolve into each other in a short time because the orientations are hard to change.

A team led by Prof. Xue-Bing Wu, a professor at Dept. of Astronomy, has conducted a survey of changing-look quasars in the last two years. They have discovered 21 changing-look quasars at redshift from 0.08 to 0.58, including 5 from repeat spectra in SDSS archive, 10 from repeat spectra in SDSS and LAMOST, and 6 from new spectroscopic observations of photometric variability selected candidates with the 2.16m Xinglong telescope at NAOC. These discoveries almost double the number of changing-look AGNs. The result was announced in a paper published in Astrophysical Journal on August 1st, 2018, with Qian Yang, a PhD student recently graduated from KIAA, being the first author.

The spectral transition time scale is from 1 to 13 years for these 21 new changing-look quasars, which confirms the dramatic changes in very short time. When the quasars "turn on (turn off)", the optical and mid-infrared radiation become stronger (weaker). The colors of these quasars become "bluer-when-brighter" in optical, but "redder-when-brighter" in mid-infrared. This may be due to the stronger influences by the hot dust on the longer-wavelength mid-infrared radiation than the shorter-wavelength mid-infrared radiation when the AGN activity becomes stronger. The results are not consistent with the ideas of the varying obscurations and tidal disruption events proposed for changing-look AGN, and support the idea of the rapid change of accretion rates in the inner part of accretion disks.

系所中心研究亮点 | *Highlights*

The physics mechanisms for changing-look AGN are crucial to understand the evolution of AGN. Now Prof. Xue-Bing Wu's team is doing more spectroscopic observations on many changing-look quasars with the domestic and international telescopes. More and more changing-look quasars are expected to be found, which will be absolutely helpful to probe the nature of these rare objects in the Universe.

Paper link：http://iopscience.iop.org/article/10.3847/1538-4357/aaca3a

二、从理论上发现"二重唱"的新型引力波天体

物理学院天文系的陈弦助理教授与合作者从天体物理动力学理论出发，提出并阐释了一类新的引力波天体的形成和演化过程。和此前已知的其他引力波源不同，这类新的天体同时辐射毫赫兹和百赫兹两种频率的引力波，因此可能被空间和地面引力波探测器同时观测到。

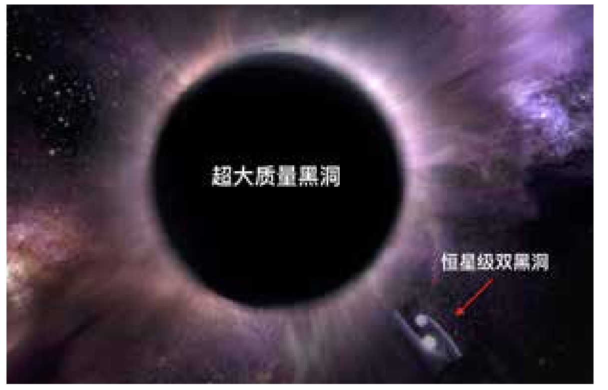
引力波是爱因斯坦广义相对论的预言。自 2015 年 9 月 14 日美国的激光干涉引力波天文台（Laser Interferometer Gravitational-wave Observatory，简称 LIGO）首次探测到两个黑洞合并所激发的引力波后，引力波天文学立刻升级成为一门新兴的实测科学。传统的天体物理动力学理论预言：一个数百万倍太阳质量的超大质量黑洞和一个数十倍太阳质量的恒星级黑洞会形成"极端质量比旋进系统"，即 extreme-mass-ratio inspiral，简称"EMRI"。这种系统会辐射 0.001 赫兹左右的低频引力波。这种引力波是未来的空间引力波探测器，比如欧美的激光干涉空间天线（Laser Interferometer Space Antenna，简称"LISA"）和中国提出的"太极"、"天琴"等计划，最重要的探测目标之一。

通过研究 EMRI 的形成机制，陈弦与其合作者发现其中的"小家伙"其实可能是由两个恒星级黑洞组成的双星（binary）。他们把这种恒星级双黑洞和超大质量黑洞组成的三体系统称作"双星极端质量比旋进系统"，即 binary extreme-mass-ratio inspiral，简称"b-EMRI"（如图一所示）。他们详细阐述了恒星级双黑洞如何被超大质量黑洞潮汐捕获（图二中 i 过程），又是如何旋进（inspiral）到超大质量黑洞几十倍视界半径处，从而可能被空间低频引力波探测器观测到（见图二中 ii 过程）。

这项工作的独到之处在于作者引入了先进的相对论三体数值模拟技术，用于追踪恒星级双黑洞在超大质量黑洞附近的动力学演化。因此他们发现两个恒星级黑洞有较高的概率并合，从而辐射地面天文台也能够探测到的高频引力波（见图二中 iii 过程）。

因为 b-EMRI 同时辐射低、高频两种引力波，就像高、低两声部同时进行演唱，所以作者形象的称之为"二重唱"引力波天体。未来联合地、空探测器寻找到这类天体，将有助于人们进一步理解引力波的产生、传播、以及强引力场所造成的多种非线性动力学过程。

该研究成果发表在《通讯物理》（Nature Publishing《Communications Physics》）上。原文网址：https://www.nature.com/articles/s42005-018-0053-0



图一：双星极端质量比旋进系统想象图。

Figure 1：Illustration of a binary extreme-mass-ratio inspiral.

II. Gravitational Wave Sources Performing a Duet

Xian Chen, an assistant professor at the Department of Astronomy, proposed with his collaborators a model for the formation and evolution of a new type of gravitational wave source. Unlike other known sources, this new object emits gravitational waves in both the milli-Hertz and the hundred-Hertz bands, and hence can be simultaneously detected by ground- and space-based detectors.

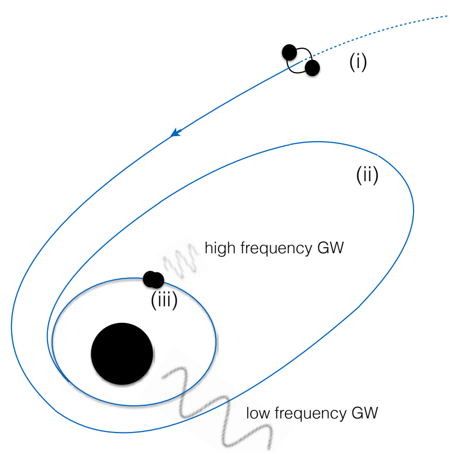
Gravitational wave is an important prediction of Einstein's General Relativity. The first detection of gravitational waves was made in 14 September 2019 by the Laser Interferometer Gravitational-wave Observatory (LIGO), where the first signal was from two merging black holes. Since then, astronomy has entered the gravitational wave era. Astrophysical theories also predict that a supermassive black hole of millions of solar masses could occasionally capture a stellar-mass black hole of about ten solar masses, and form a two-body system called "extreme-mass-ratio inspiral" (EMRI). Such a system emits gravitational waves in the milli-Hertz band. It is among the major targets of the future space-based detectors, such as the Laser Interferometer Space Antenna of the European Space Agency, or China's Taiji and Tianqin projects.

Xian Chen and his collaborators studied the formation mechanism of EMRI and discovered that the "small guy" in it, in fact, could be a binary composed of two stellar-mass black holes. They call such a triple system "binary extreme-mass-ratio inspral" (b-EMRI, see Figure 1). They also described in detail how a small black hole binary could be tidally captured by a supermassive one (see process i in Figure 2), spiral inward to tens of Scharzschild radii of the supermassive black hole, and finally be detected by a space-borne low-frequency gravitational wave detector (process ii in Figure 2).

The authors used state-of-the-art numerical three-body simulations to follow the dynamical evolution of the small binary around the big black hole. They found that the binary has a large probability to coalesce, and hence also emit high-frequency gravitational waves which can be detected as well by a ground-based detector (see process iii in Figure 2).

Because a b-EMRI emits both low- and high-frequency gravitational waves, it is similar to having two instruments performing a duet. The future joint observation of such an object by the ground and space detectors could help us further understand the generation and propagation of gravitational waves, as well as the non-linear dynamical processes in the regime of strong gravity.

This work is published in the journal of Communications Physics (Nature Publishing). Full article link: https://www.nature.com/articles/s42005-018-0053-0



图二：b-EMRI 系统的形成 (i)、绕进 (ii)、和终结 (iii) 示意图。

Figure 2: The (i) formation, (ii) inspiral, and (iii) termination of a binary extreme-mass-ratio inspiral.

三、基于国家大科学装置 LAMOST 新发现两颗超高速恒星

天文系黄样、刘晓为、张华伟等人使用国家大科学装置郭守敬望远镜（大天区面积多目标光纤光谱天文望远镜，英文简称 LAMOST）大规模银河系光谱巡天的数据新发现两颗距地球 7 万多光年的超高速星，分别命名为 LAMOST-HVS2 和 LAMOST-HVS3。这是基于 LAMOST 大规模银河系光谱巡天发现的第二和第三颗超高速星。

银河系中的大多数恒星都像太阳一样以约 200 千米每秒的速度绕银河系中心运动。所谓超高速星是指一类速度高到能够脱离银河系引力束缚的恒星，如果寿命允许，它们将最终飞出银河系。20 世纪 80 年代末，美国洛斯阿拉莫斯国家实验室天体物理学家杰克·希尔提出，运动到银河系中心超大质量黑洞附近的双星系统有可能被黑洞巨大的潮汐力所瓦解，被瓦解的双星系统的一颗被高速抛出，成为超高速星。该预言提出近 20 年之后，美国哈佛 - 史密森天体物理中心科学家沃伦·布朗才第一次在银河系中探测到此类恒星。探测超高速星极为困难，迄今为止，天文学家也仅仅在数千亿颗银河系恒星中证认出了 20 余颗此类恒星，远低于银河系有超过 1000 颗超高速星的理论预言。

此次现的两颗超高速星均是离银河系中心较近的明亮天体。其中 LAMOST-HVS2 与此前郑政等人基于 LAMOST 数据发现的首颗超高速星 LAMOST-HVS1 有着相近的银心距，是目前发现的距银心最近的超高速星。这非常有利于对它们进行更为细致的后续观测和研究。尤其是结合欧空局新一代天体测量卫星 Gaia 即将释放的高精度自行数据之后，将有望对超高速星的产生机制、银河系中心超大质量黑洞的性质以及银河系暗物质晕的质量分布给出极为严格的约束。

相关发表文章：

Huang, Y., Liu, X.W., Zhang, H.W. et al., (2017), ApJL, 847, 9

相关报道：

https://www.universetoday.com/137100/chinese-astronomers-spot-two-new-hypervelocity-stars/

https://phys.org/news/2017-09-distant-hypervelocity-stars-chinese-astronomers.html

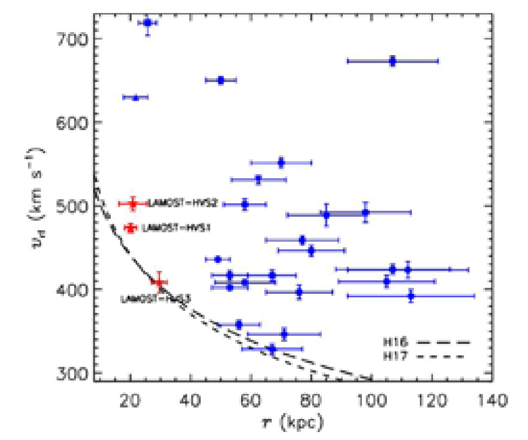


图 1：超高速恒星的银心距与视向速度分布

Figure 1: Radial velocity and Galactocentric radius of HVS

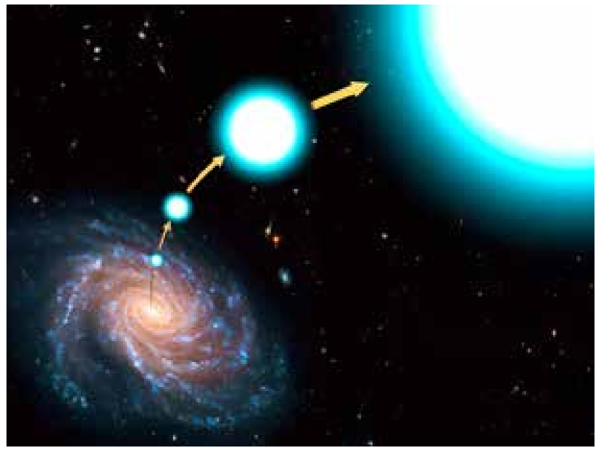


图 2：高速星逃逸银河系的示意图（来源 NASA）

Figure 2: Artist's impression of hypervelocity stars (HVSs) speeding through the Galaxy. Credit: NASA

III. Two distant hypervelocity stars discovered by using LAMOST data

A group of Chinese astronomers led by Yang Huang, Xiaowei Liu, Huawei Zhang has detected two new unbound hypervelocity stars located over 70,000 light years away. The discovery could help scientists better understand the nature of these rare, peculiar stars.

Hypervelocity stars (HVSs) are rare objects with velocities so great that they exceed the escape velocity of the galaxy. Astronomers believe that they originate near the center of the Milky Way galaxy by dynamical interactions between binary stars and the central massive black hole. While ordinary stars have velocities around 100 km/s, the velocities of HVSs can reach even 1,000 km/s.

Although scientists estimate that approximately 1,000 HVSs exist in the Milky Way, only about 20 such stars have been identified so far. Given that these objects travel large distances across our galaxy, they could serve as powerful tracers to probe the mass distribution in the Milky Way, providing crucial information about the shape of the galactic dark matter halo. Therefore, finding new HVSs could help us build a valuable database of such tracers.

With this aim in mind, Huang's team have analyzed the available data provided by the LAMOST spectroscopic surveys. The surveys, utilizing the Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST) in China, investigate the structure and evolution of our galaxy, and have already located one hypervelocity star.

Now, the Chinese astronomers report the finding of two new HVSs in the latest data release from the LAMOST surveys. The researchers found two new unbound hypervelocity stars, designated LAMOST-HVS2 and LAMOST-HVS3.

Published paper:

Huang, Y., Liu, X.W., Zhang, H.W. et al., (2017), ApJL, 847, 9

News:

https://www.universetoday.com/137100/chinese-astronomers-spot-two-new-hypervelocity-stars/

https://phys.org/news/2017-09-distant-hypervelocity-stars-chinese-astronomers.html

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

北京大学大气与海洋科学系起源于 1929 年，具有悠久的历史和优良的传统。近 90 年来，大批杰出学者先后在此执教或学习，秉承自由、严谨、求实、创新的精神，为大气与海洋科学教育、科研和业务做出了卓越贡献。

本系是中国高校中唯一的大气科学一级重点学科，拥有两个二级重点学科（气象学、大气物理学与大气环境），自设两个二级学科（气候学、物理海洋学），强调各学科方向的均衡发展。1993 年，本系被确定为第一批“国家理科基础科学研究和教学人才培养基地 - 大气科学基地”。2008 年，本系与北京大学其它地球科学学科共同成立了国家级“地球科学教学实验中心 - 大气科学综合实验室”。2010 年，为加强气候变化研究和开展海洋科学研究，增设了物理海洋专业，成立了“气候与海气实验室”。

本系现有 28 名全职教师，包括杰青 3 人、优青 1 人、青年拔尖 1 人。研究方向涵盖天气、气候、大气物理、大气化学与环境、物理海洋及行星大气，聚焦基础与前沿科学问题，提倡在独立科研基础上的跨领域团队合作，致力于建设世界一流的大气与海洋科学学科。近年来，教师人均每年获得科研经费约 90 万元，人均每年发表 SCI 论文 3.5 篇（其中第一署名 2.3 篇）。

The Department of Atmospheric and Oceanic Sciences (AOS) at Peking University originated from a meteorological program established in 1929, and has a long and prestigious history of academic excellence. Over the past 90 years, many prominent scholars have taught or studied at AOS. Immersed in an environment of academic freedom, rigor and innovation, AOS scholars have made extraordinary contributions to education, fundamental research, and applications of atmospheric and oceanic sciences to the betterment of society.

AOS has the only first-tier focal discipline in atmospheric sciences in China. It has two second-tier focal disciplines (meteorology, atmospheric physics and atmospheric environment), and two more second-tier disciplines (climatology and physical oceanography). In 1993, AOS was selected in the first group of “National Natural Science Basic Scientific Research and Teaching Training Base — Atmospheric Science Base”. In 2008, AOS established jointly with other Earth Science disciplines at PKU the national-level “Earth Science Teaching and Experiment Center — Atmospheric Science Laboratory”. In 2010, AOS added the Physical Oceanography program, and established the “Laboratory for Climate and Ocean-Atmosphere Studies”.

AOS employs a total of 28 full-time faculty members, including 3 National Outstanding Early-Career Scientists, 1 National Outstanding Early-Career Scientist, 1 Qing Nian Ba Jian Scholar, Research fields within AOS cover meteorology, climatology, atmospheric physics, atmospheric chemistry, environmental science, physical oceanography, and planetary atmospheres. AOS actively pursues fundamental and cutting-edge research, promotes multidisciplinary collaborations on the basis of independent research, and strives to become a world-leading institution in atmospheric and oceanic sciences. In each of recent years, each faculty member received about 900,000 RMB research funds and published 3.5 SCI papers (including 2.3 papers with Peking University as the first affiliation).

一、国际贸易与大气输送引起的 $PM_{2.5}$ 健康效应

根据世界卫生组织的估计，与 $PM_{2.5}$ 相关的室外空气污染导致全球每年 300 多万人过早死亡。$PM_{2.5}$ 污染的产生与各类消费产品生产和运输过程中的能源消耗和污染物排放密切相关。传统上认为空气污染主要影响本地空气质量，其中一小部分会通过大气输送对下游地区造成影响。在经济全球化背景下，由于国际贸易的存在，产品生产从消费地区转移到生产地区，与之相关的污染物排放也随之发生转移，从而改变了大气污染物排放的时空分布特征，并进一步对各地区的空气质量和人群健康产生影响。然而，相关的研究极少，缺乏清晰的定量认识。

由物理学院大气与海洋科学系林金泰课题组和

清华大学合作者共同领导的国际团队自 2011 年开始研究消费和贸易相关的空气污染问题，探究经济贸易与大气输送的耦合引起的全球化大气污染及其气候环境影响，研究成果陆续发表在 PNAS（获得 Cozzarelli 奖）、Nature Geoscience 等重要国际期刊上。

2017 年 3 月 30 日，该团队在 Nature 期刊发表题 为“Transboundary health impacts of transported global air pollution and international trade”的论文，首次定量揭示了全球贸易活动及其与大气输送之间的耦合所引起的 $PM_{2.5}$ 跨境污染的健康影响。该研究将全球划分为十三个区域，通过耦合排放清单模型、投入产出模型、大气化学传输模型和健康效应模型，发现 2007 年与国际贸易相关的 $PM_{2.5}$ 污染跨境污染要远高于与大气输送相关的跨境污染。在国际贸易与大气输送的协同作用下，由于全球消费地区与生产地区的不同引起了严重的 $PM_{2.5}$ 跨境污染，其造成全球每年约 76 万人过早死亡，约占全球由于 $PM_{2.5}$ 污染造成的过早死亡人数的 22%。国际贸易使中国、印度、东南亚、东欧等地区的 $PM_{2.5}$ 污染暴露和过早死亡人数增加，而使美国、西欧、日本等地区的过早死亡人数减少，这就意味着污染通过国际贸易从发达地区转移到了发展中地区。通过大气输送过程，某一地区的生产和消费引起的 $PM_{2.5}$ 污染导致了世界多个地区的过早死亡（图 1）。该研究揭示了空气污染在经济全球化背景下已成为一个全球问题。发展中国家应该加速减排；国际社会应当提倡可持续消费，并通过建立相关合作机制促进技术转移，从而降低贸易中隐含的污染水平，推动空气污染全球治理。

清华大学地球系统科学系张强教授及其研究组成员江旭佳、同丹为论文的共同第一作者，张强教授、清华大学环境学院贺克斌院士、北京大学林金泰长聘副教授和美国加州爾文分校 Steven Davis 副教授为论文共同通讯作者，林金泰研究组成员倪睿婧、燕莹莹参与了该研究。本研究工作得到了国家自然科学基金委和国家重点基础研究计划（973 计划）项目的支持。

I. $PM_{2.5}$ related premature deaths associated with international trade and atmospheric transport

According to the estimate of the World Health Organization, ambient fine particle pollution ($PM_{2.5}$) leads to more than 3 million premature deaths worldwide. $PM_{2.5}$ is produced from emissions out of economic activities producing goods and services to supply consumption. PM pollution is thought to mostly affect local air quality, with some fractions being transported in the atmosphere to long distances. The current economic globalization means that production of goods and associated emissions is transferred from regions consuming to regions producing those goods. This results in significant redistribution of emissions and pollution worldwide, with important consequences on air quality and human health. Yet there remains little quantitative understanding on the extent to which such transboundary pollution would led to premature mortality.

Starting from 2011, Professor Jintai Lin’s group in the Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University and collaborators at Tsinghua University have co-led an international collaborative team to analyze the atmospheric environmental problems related to consumption and trade, particularly on how trade activities are coupled with atmospheric transport processes to lead to globalizing air pollution and resulting environmental and climate impacts. To date, the team has published a series of papers on this topic in PNAS (Cozzarelli Prize winner), Nature Geoscience and other journals.

On March 30th, 2017, the team published another paper entitled “Transboundary health impacts of transported global air pollution and international trade” in Nature, which revealed for the first time the global premature deaths from ambient $PM_{2.5}$ pollution as a result of economic trade and atmospheric transport. This work reveals that $PM_{2.5}$ pollution associated with the coupled effect of global trade and atmospheric transport is associated with about 760,000 mortalities worldwide in 2007, contributing 22% of all $PM_{2.5}$ related deaths. Trade-related pollution transfer is more effective than atmospheric transport in causing redistribution of premature deaths. China, India and other developing countries are net exporters of goods, and the developed countries are net importers. As a result, trade means increased pollution and deaths in the developing countries and reduced deaths in the developed countries. Atmospheric transport means that both production and consumption by a particular region leads to PM pollution and mortalities worldwide (Fig. 1). This study reveals the link between production, consumption, trade, pollution transfer and public health, and it calls for fastened emission reduction in the developing countries as well as improved global collaboration to reduce pollution by accounting for the role of consumption and trade in redistributing pollution.

Professor Jintai Lin is a co-corresponding author of the paper, together with Professors Qiang Zhang and Hebin He at Tsinghua University and Professor Steven Davis at the University of California, Irvine. Qiang Zhang and his team members Xujia Jiang and Dan Tong are the joint first authors. Ruijing Ni and Yingying Yan in Jintai Lin’s group also participate in the study. The study was funded by NSFC and the 973 Project.

Paper:

Zhang, Q. #*, Jiang, X. #, Tong, D. #, Davis, S. J. *, Zhao, H., Geng, G., Feng, T., Zheng, B., Lu, Z., Streets, D. G., Ni, R.-J., Brauer, M., van Donkelaar, A., Martin, R. V., Huo, H., Liu, Z., Pan, D., Kan, H., Yan, Y.-Y., Lin, J.-T. * , He, K. *, and Guan, D.: Transboundary health impacts of transported global air pollution and international trade, Nature, 543, 705-709, doi:10.1038/nature21712, 2017, http://www.nature.com/nature/journal/v543/n7647/full/nature21712.html

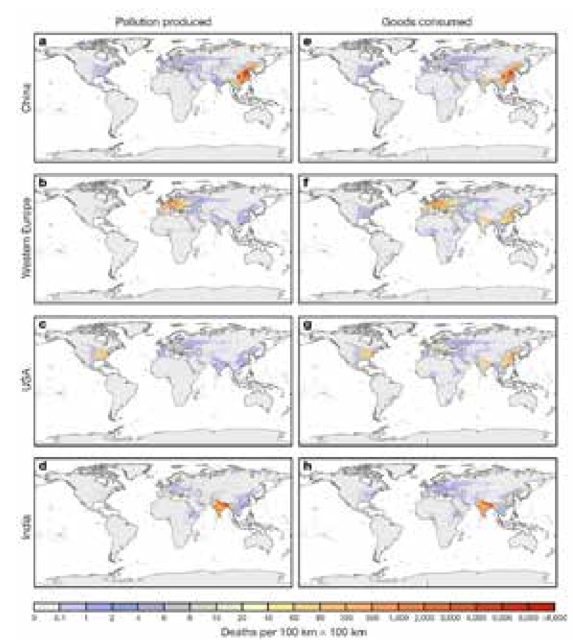


图 1：中国、西欧、美国、印度的生产（左）和消费（右）引起的排放 - 污染 - 大气输送导致的 PM2.5 相关过早死亡人数的空间分布。来源：Zhang et al., 2017, Nature。

Figure 1. Global distribution of premature deaths due to ambient PM2.5 pollution as a result of production (left) and consumption (right) of goods and services in China, Western Europe, the United States and India. Source: Zhang et al., 2017, Nature.

Related papers:
(1)Lin, J.-T. #*, Pan, D. # , Davis, S. J., Zhang, Q. *, He, K. *, Wang, C., Streets, D. G., Wuebbles, D. J., and Guan, D.: China’s international trade and air pollution in the United States, Proceedings of the National Academy of Sciences of the United States of America, 111, 1736-1741, doi:10.1073/pnas.1312860111, 2014, http://www.pnas.org/content/111/5/1736.short
(2)Guan, D.-B., Lin, J.-T. *, Davis, S. J., Pan, D., He, K.-B., Wang, C., Wuebbles, D. J., Streets, D. G., and Zhang, Q.: Reply to Lopez et al.: Consumption-based accounting helps mitigate global air pollution, Proceedings of the National Academy of Sciences of the United States of America, 111, E2631, doi:10.1073/pnas.1407383111, 2014, http://www.pnas.org/content/111/26/E2631.full
(3)Lin, J.-T. #*, Tong, D. #, Davis, S., Ni, R.-J., Tan, X., Pan, D., Zhao, H., Lu, Z., Streets, D., Feng, T., Zhang, Q. *, Yan, Y.-Y., Hu, Y., Li, J., Liu, Z., Jiang, X., Geng, G., He, K., Huang, Y. *, and Guan, D.: Global climate forcing of aerosols embodied in international trade, Nature Geoscience, 9, 790-794, doi:10.1038/NGEO2798, 2016 , http://www.nature.com/ngeo/journal/v9/n10/abs/ngeo2798.html

二、极端降雨的气候响应

极端降雨常导致洪涝、泥石流等重大灾害，给社会经济和生态环境带来极大影响。在全球变暖的气候背景下，近年来很多区域的强降雨等极端天气发生的频率或强度显著增加。当气候变暖时，空气中水汽的含量会增多，导致降雨发生时的雨量也会增多。如果只考虑大气水分增加，那么极端降雨强度随温度的增幅应为约 7%每度。然而，在实际天气过程中，大气运动对降雨的影响也至关重要，而这方面的研究由于其复杂性而非常薄弱。

针对极端降雨中的大气运动和其对气候变化的响应，聂绩研究员和合作者使用一个新颖简化的模型，通过模拟美国 2015 年 5 月的一次灾害性极端降雨过程，量化分析了大气大尺度运动和小尺度对流之间的耦合，同时模拟了在工业化增温前（较于现在气温低 1.5 度）和本世纪末（较于现在增温 4.5 度）的情景下，发生在同一地区的极端降雨事件产生的降雨量差异。总结数值结果表明，在更暖的气候下的背景下，由于大气中的水汽增多（7%每度），凝结释放的潜热也会增多，导致更强的大气抬升运动。其结果是极端降雨事件随气温的增加可能会是单纯水汽增多的效果的两倍左右（～ 14%每度）。该研究为理解极端降雨事件对全球变暖的响应提供了新的认识，所使用的模拟和分析方法为理解极端降雨气候响应的区域特征提供了新的思路。

论文：
Nie, J.*, A. H. Sobel, D. A. Shaevitz, and S. Wang, 2018: Dynamic Amplification of Extreme Precipitation Sensitivity, Proc. Natl. Acad. Sci., 115, 9467-9472.
http://www.pnas.org/content/early/2018/08/28/1800357115

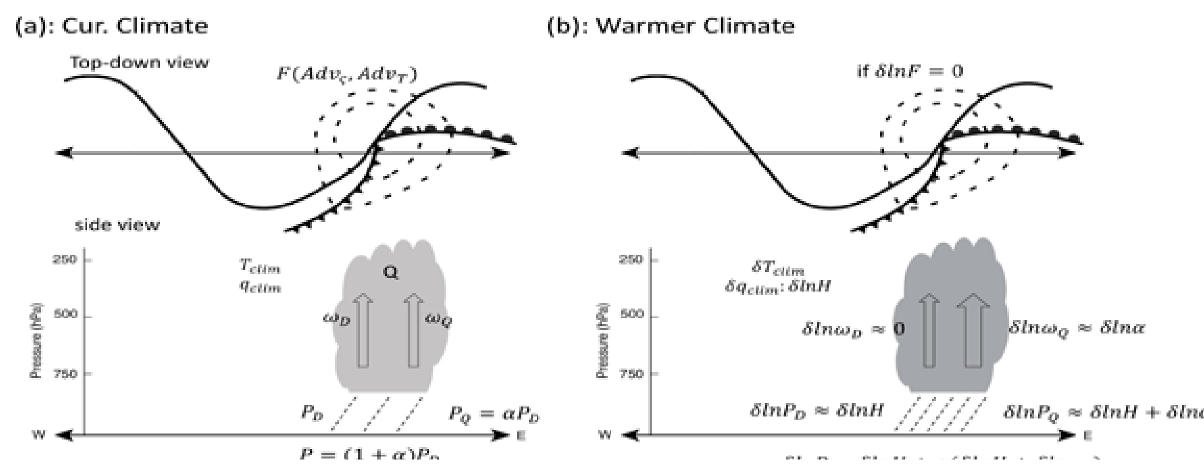


图 1：极端降雨在当前气候下的主要过程（a）和其对气候暖化的响应（b）的示意图。

Fig. A schematic of the scaling of precipitation extremes with temperature in a CQG system. (a) is under the current climate, and (b) is in a warmer climate.

II. Climate responses of extreme precipitation

Extreme precipitation often leads to major disasters such as floods and landslides, which have great impacts on the social economy and the environment. Under global warming, in most regions the frequency and intensity of extreme precipitation have increased significantly in recent years. As the atmosphere warms, the amount of water vapor in the air increases, resulting in an increase in precipitation amount when rainfall occurs. With this thermodynamical consideration only, the increase in extreme precipitation intensity with temperature should be about 7% per degree of warming. However, the effects of atmospheric motion in rainfall are also critical. However, due to its complexity, studies in this area are very limited

Dr. Ji Nie and his collaborators use a novel simplified model to address the dynamic effects of extreme precipitation and its response to climate change. They use this model simulated an extreme rainfall event occurred in the United States in May 2015, with focus on the coupling between motion and small-scale convection. They further modeled extreme rainfall with similar synoptic conditions but under climate scenarios before industrial warming (1.5 degrees lower than current temperature) and at the end of the century (4.5 degrees higher than the current temperature increase). The numerical results show that in the warmer climate, due to the increase of atmospheric water vapor (7% per degree), the latent heat released by condensation will increase, leading to a stronger atmospheric uplift. As a result, the extreme rainfall may increase by about twice the effect of simple water vapor increase (~14% per degree). The study deepens the understanding of the extreme precipitation, and provide insights into the regional responses of extreme precipitation to climate change.

三、从冰雪世界到湿温室或失控温室的气候转变

生命存在的首要条件是液态水。一颗行星是否适宜生命生存取决于其表面温度能否维持液态水。以太阳系为例，金星太热（其表面温度超过500℃）、火星太冷（表面温度低于-60℃），均不适宜生命存在，只有地球表面有液态水存在，因此地球适宜人类生存。位于火星位置以外的固态星体（如冥王星、木星的卫星欧罗巴和土星的卫星恩克拉多斯）其成分主要为水，但因温度太低，水均以冰的形式存在。

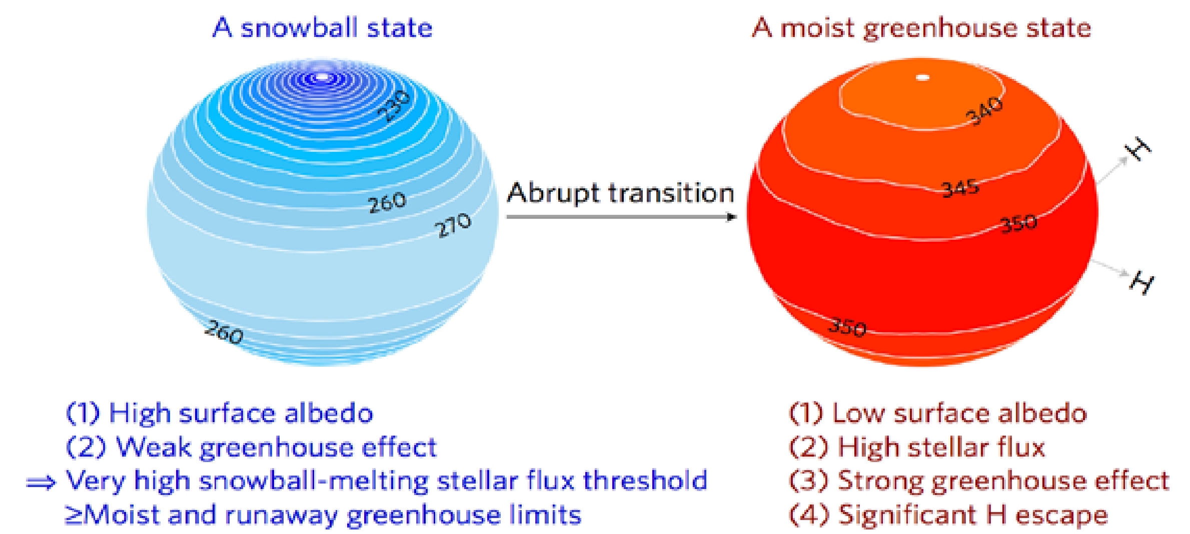
根据恒星演化理论，一颗恒星在其演化过程中因其内部核聚变反应愈来愈强，其向外的辐射能量愈来愈强。过去学者们通常认为，随着恒星辐射的增强，原来的冰行星或卫星最终会融化形成液态水，从而适宜生命存在。但杨军和胡永云等根据理论研究和大量数值模拟提出：这些冰行星或卫星很可能在将来是非宜居的。他们的研究结果表明，随着恒星辐射增强，这类冰行星或卫星将直接进入极端炎热的温室逃逸状态，也就是说它们的表面温度将升高到100℃以上，液态水因而无法存在，生命也将无法存在。

随着恒星辐射增强，冰行星或卫星的气候状态随之发生突变，而不是平缓过渡到温和的宜居状态，是因为其表面反射恒星辐射能力的急剧降低和大气温室效应的急剧增强造成的。冰雪能够把60%以上的恒星辐射反射回太空，而液态水仅反射不足10%的恒星辐射。一旦冰雪融化，行星地表反射能力的突然降低使得其吸收恒星辐射的能力大大增强，从而导致地表温度急剧升高。除此之外，冰雪融化后，大量的水汽进入大气，水汽的强温室效应也将使地表温度进一步升高。在水汽正反馈效应的作用下，液态水将完全蒸发进入大气并被光解、最终逃逸至太空。该项研究从根本上改变了科学家关于冰行星和卫星气候演化及其宜居性的认知。

加州理工学院行星科学家 Andrew Ingersoll 教授应 Nature Geoscience 邀请为该论文写了评论。他指出，杨军及其合作者的研究结果表明：冰行星变为宜居星球并不是冰融化为水那么简单，冰行星或卫星的气候演化将跳过宜居状态，直接从极端寒冷变为极端炎热的气候态。Nature 也对本该文章进行了亮点报导，指出，杨军团队的研究发现，融化冰行星所需要的恒星辐射是如此之强，以至于冰行星跳过温和、适宜生命存在的气候态，直接进入足以让水沸腾和完全蒸发的气候态。

III. Abrupt Climate Transition of Icy Worlds from snowball to moist or runaway greenhouse

Ongoing and future space missions aim to identify potentially habitable planets in our Solar System and beyond. Planetary habitability is determined not only by a planet’s current stellar insolation and atmospheric properties, but also by the evolutionary history of its climate. It has been suggested that icy planets and moons become habitable after their initial ice shield melts as their host stars brighten. Here Jun Yang's team shows from global climate model simulations that a habitable state is not achieved in the climatic evolution of those icy planets and moons that possess an inactive carbonate–silicate cycle and low concentrations of greenhouse gases. Examples for such planetary bodies are the icy moons Europa and Enceladus, and certain icy exoplanets orbiting G and F stars. Yang finds that the stellar fluxes that are



从冰雪世界到极端炎热世界的快速转换

Abrupt transition from a snowball state to an extremely hot climate state

required to overcome a planet’s initial snowball state are so large that they lead to significant water loss and preclude a habitable planet. Specifically, they exceed the moist greenhouse limit, at which water vapour accumulates at high altitudes where it can readily escape, or the runaway greenhouse limit, at which the strength of the greenhouse increases until the oceans boil away. We suggest that some icy planetary bodies may transition directly to a moist or runaway greenhouse without passing through a habitable Earth-like state.

Icy worlds are common in the Solar System (such as Europa, Enceladus, Ganymede and early Earth) and plausibly also in extrasolar systems. A fundamental question is: would such icy planets and moons become habitable once their ice cover melts? There are two ways for the icy worlds to escape the globally ice-covered snowball states. One is that continuous atmospheric accumulation of CO2 from volcanic outgassing during the snowball phase triggers the melting; this is plausible for planets having an active carbon cycle (for example, Earth), and they become habitable for life after the ice melts. The other is that the stars brighten with time and the ice melts once the stellar flux exceeds a critical value; this is the case for planets and moons lacking an active carbon– silicate cycle and having low concentrations of greenhouse gases (for example, Europa). Here, Yang's team investigates the second case using a series of three-dimensional (3D) climate model experiments. In contrast to previous studies that suggest the existence of a habitable world after the snowball deglaciation, they show that the increased stellar insolation will force the planet into an uninhabitable moist or even runaway greenhouse state.

For details, please see the paper online: https://www.nature.com/articles/ngeo2994

08 普通物理教学中心 Teaching Center for 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.

一、 北京大学慕课《电磁学》被认定为“2018 年度教育部国家精品在线开放课程”

《电磁学》课程组注重课程建设，在北京大学几代教师辛勤耕耘下，课程体系更趋成熟、完善，形成了“立论严谨、深入浅出、物理图象清晰”的优良教学风格，教材建设成果显著，历年的教学效果好，各个教学班均受到广大学生的欢迎。该课程于 2003 年被评为第一批国家精品课程，2013 年被评为国家级精品资源共享课。2018 年被认定为“2018 年度教育部国家精品在线开放课程”。

慕课是近年来教育界的新生事物，为了传承北京大学普通物理优良的教学传统，进一步宣传北京大学基础课教学理念，让更多学生共享北京大学教学资源，电磁学课程组于 2014 年将北京大学普通物理 04 系列课程中的电磁学课程改编成慕课《电磁学》，2014 年首先在 Coursera 平台上上线，2016 年移到华文慕课平台上，2018 年，在爱课程中国大学 Mooc 平台上开课。

考虑到课程的受众主要是在校大学低年级学生、中学教师及学有余力的中学生，慕课《电磁学》定位于一个学生自学电磁学的辅助系统，尽可能反应北大 04 系列电磁学原汁原味的教学理念、教学面貌和提供比较丰富的教学资源。为了便于学生自主学习，将课程设置成全程开放的自主课程，每个模块附有练习题，学生可以任意选取需要的章节学习、练习，不必跟着网站发布节奏学习。自助课程有利于学生按照自己的需要和进度完成学习，课程开放后获得了很好的效果，既有利于系统学习的学生利用慕课学习，也有利于在校学生作为辅助资料，自我补漏拾遗。《电磁学》开课以来受到选修者的欢迎和好评，特别是对于教学资源不太丰富的高校和地区，是一种教学资源的补充，对于学有余力的中学生，也提供了一个提高水平的平台。

课程组团队由王稼军教授主持，团队主要成员是穆良柱，孟策，陈晓林。目前在中国大学 Mooc 平台上，已经完成了两个学期，第三个学期正在进行中，由张海君负责课程的资料的上载和维护。

I. The course on electromagnetism awarded as one of the 2018 National Quality MOOCs by the National Ministry of Education

For generations, the teachers of this course have been focusing on the curriculum construction. Now, the course is fully developed, emphasizing on rigorous reasoning, using simple cases for examples and demonstrating complicate theories with clear physical vision. Several textbooks have been published based on the lecture notes of these teachers and were welcome by many thousands of undergraduate students. In addition, the course was also awarded as one of the National High-quality Courses in 2003 and the National High-quality Resource Sharing Courses in 2013 by the National Ministry of Education.

MOOC is a new way of education developed in recent years. In order to promote the teaching of the general physics at Peking University and give more students opportunity to share resources, the teachers of electromagnetism made the MOOC version of this course in 2014 and put it on Coursera web. Then, in 2016, it was transferred to Chinesemooc and was eventually opened to public on the Icourses web in 2018.

Since most of the students of this course are junior undergraduates or high school teachers, the MOOC version of electromagnetism course is designed to be a self-study system. Therefore, great efforts have been made to preserve the same teaching quality at Peking University and, in the meantime, give also plenty of teaching resources. For student’s convenience, several modules with exercises are provided. As a result, students can arrange their own learning process and have no need to follow the web schedule. The course is of great use to both kinds of students who want either learning the course by themselves or using it as a complementary resource. As a matter of fact, since the opening of this course, it has been welcome by students and teachers of the colleges with less teaching resources. Especially, the course was taken by many excellent high school students as advanced preparations for college.

The course team is led by Professor Jiajun Wang and the team members are Liangzhu Mu, Ce Meng and Xiaolin Chen. Up to now, two teaching sessions have been completed, and the third session is carrying on. Haijun Zhang is in charge of the maintenances of this course.

二、中国代表队参加第 18 届亚洲物理奥赛和第 48 届国际物理奥赛获得优异成绩

2017 年国际和亚洲物理奥赛代表队的集训、选拔等工作由北京大学物理学院负责，普物教学中心负责理论课程培训。中国物理奥赛集训队共选拔出 13 名学生，前 5 名组成国际物理奥林匹克竞赛中国代表队，后 8 名组成亚洲物理奥林匹克竞赛中国代表队。国际赛代表队参加了在印尼日惹举办的第 18 届国际物理奥赛，队员总分排名2-6名，获得5枚金牌，并获理论第一、团体第一。亚洲赛代表队参加了在俄罗斯雅库茨克举办的第 18 届亚洲物理奥赛，总分排名 1-3，5-9，获得 8 枚金牌，并获总分第一、实验第一、理论第一、最佳男选手、最佳解题奖、团体第一。中国代表队在两次比赛中取得了优异的成绩。

参加第 48 届国际物理奥林匹克竞赛的中国队合影（从左到右，穆良柱、洪千坦、高昊阳、汪品源、王准、郑希诠、杨景、陈晓林）Chinese team for the 48th International Physics Olympiad(From left to right, Liangzhu Mu, Qiantan Hong, Haoyang Gao, Pinyuan Wang, Zhun Wang, Xiquan Zheng, Jing Yang, Xiaolin Chen)

参加第 18 届亚洲物理奥林匹克竞赛的中国队合影（从左至右，陈晓林、杨景、俞启威、王秋原、甘天奕、朱尧峥、汪弘毅、姚志睿、姚铭星、王竟先、穆良柱）Chinese team for the 18th Asian Physics Olympiad(From left to right, Xiaolin Chen, Jing Yang, Qiwei Yu, Qiuyuan Wang, Tianyi Gan, Yaozheng Zhu, Hongyi Wang, Zhirui Yao, Mingxing Yao, Jingxian Wang, Liangzhu Mu)

II. Chinese teams have achieved excellent results in the 18th Asian Physics Olympiad and the 48th International Physics Olympiad

The training and selection of the 2017 International and Asian Physical Olympiad teams was undertaken by the School of Physics of Peking University, and the Teaching Center for General Physics was responsible for the theoretical courses. 13 students were selected, the top 5 formed the Chinese team for the 48th International Physics Olympiad, and the last 8 formed the team for the 18th Asian Physics Olympiad. The 18th International Physics Olympiad was held in Yogyakarta, Indonesia. The Chinese team members ranked 2-6 on the ranking list and won 5 gold medals. They won the Best Theory Award and the Best Group Award, too. The 18th Asian Physics Olympics was held in Yakutsk, Russia. The Chinese team members ranked 1-3, 5-9 on the ranking list, and won 8 gold medals. They also won the First Award, the Best Experiment Award, the Best Theory Award, the Best Male Player, the Best Solution Award, the Best Group Award. The Chinese teams have achieved excellent results in these two competitions.

09 基础物理实验教学中心 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”和“前沿物理实验”选修课。目前在岗专职教师 9 名（教授 3 名，副教授 6 名），实验技术人员 7 名（高级工程师 1 名，工程师 6 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 research courses called “Comprehensive Physics Experiment” and “Frontier Physics Experiment” to students who are willing to investigate some experimental problems. Now there are 16 faculty members in the center, in which are 3 professors, 6 associate professors, 1 senior engineer, 6 engineers.

一、“综合普物实验”课程建设取得进展

为结合传统实验教学模式和创新实验教学模式的优点，实验中心在张朝晖老师主持下新开设了“综合普物实验”课程。该课程继“普通物理实验Ⅰ”之后，与“普通物理实验Ⅱ”并行，面向“普通物理实验Ⅰ”成绩优秀的学生，按学生意愿由高分向下录取。

该课程强调学生的自主探究，学生每周有一个下午的固定时间在实验室上课，上课时教师不在现场指导。学生课前阅读教师提供的讲义，课上自主做实验，实验技术人员负责实验室管理和仪器维护，教师通过课后的一对一面谈交流对学生进行指导和考核。除固定时间外，学生还可以在其它时间自主预约加做实验。学生每人一套实验仪器，两周完成一个实验，一个学期共完成六个实验，所有实验在一个实验室循环进行，鼓励学生相互交流。

该课程内容上强调综合性和开放性。目前的六个题目分别是光学成像与光信息处理、迈克耳逊干涉与光学相关测量、基于虚拟仪器技术的弗兰克-赫兹实验、光力学效应与光镊、一维周期弦链振动、二维法拉第斑图实验观察与研究，在内容上综合力学、电学、光学、非线性物理等多个领域，涉及各类不同实验技术。题目具有良好的开放性和可扩展性，学生期中和期末要各选择一个题目，针对该题目中的某个问题进行深入的专题研究，并分别将研究结果总结为科研论文形式的书面报告和 ppt 形式的口头报告。通过以上专题研究，训练学生的基本科研能力。

该课程实施以来，受到学生很好的评价，学生普遍反应在课程中自己的动手实验能力和独立研究能力得到了充分的训练和提高。

I. Progress in the construction of Comprehensive General Physics Experiment

In order to combine the advantages of traditional teaching and innovative teaching, a new course “Comprehensive General Physics Experiment”, has been constructed under the leading of Professor Zhang Zhaohui at our center. This course is purposed for interested students with the most excellent performance in “General Physics Experiment I” as the alternate course of “General Physics Experiment II”.

The new course emphasizes on students’ independent exploration. Students have a fixed time in the laboratory one afternoon a week, while the teacher is not on-site guiding. Students need to read the handout provided by the teacher before class and do experiments independently in class. Laboratory technicians are responsible for laboratory management and instrument maintenance. Teachers guide and assess each student through the one-on-one discussion after the lab class. Besides the fixed time, students can schedule extra time to work in the lab. Each student has a set of experimental equipment. Students are required to complete 1 topic in two weeks and accomplish 6 topics in one semester. All the experiments are carried out in cycle in one large laboratory space to encourage students to communicate with each other freely.

The course emphasizes comprehensiveness and openness. The current 6 topics are, optical imaging and optical information processing, Michelson-interference and optics correlation measurement, Frank-Hertz experiment based on virtual instrument technology, photo-mechanical effect and optical tweezers, one-dimensional periodic chord chain vibration, experimental observation and study on two-dimensional Faraday pattern. The course contents combine mechanics, electricity, optics, nonlinear physics and other general physics fields, involving various experimental techniques. Each topic has the good openness and extendibility. Students need to select one topic at the mid-term and the other topic at the end of the semester to complete the in-depth research of problems. They summarize their research results, one topic as a written report in the form of scientific paper, and the other as an oral presentation to teachers and students. Through the above studies on special topics, students get trained in their basic scientific research ability.

Since its implementation, this new course has received high evaluation from students. Students totally agree that their hands-on experimental skills and their independent research abilities have been fully trained and improved through this advanced curriculum.

二、研究型实验课程继续取得成果

基础物理实验教学中心以“科研引领实验教学”的理念推动队伍和课程建设，鼓励在岗教师积极申请承担科研项目，并且给予配套经费，在基础物理实验教学的过程中插入研究型的实验课程，建设研究型的实验教学平台，培养优秀本科生的科研创新能力，取得了非常好的效果。近两年来，中心教师在研究型实验课程中指导本科生开展科研工作，本科生为第一作者的一些研究论文发表在国际重要学术刊物上。例如，基于片上集成亚波长表面等离激元波导的多通道全光控制的研究工作发表在 ACS Photonics [5, 1575–1582 (2018)]，本科生王宇晗为论文的第一作者；具有最大光强开关比的通用线性全光逻辑门的研究工作发表在 ACS Photonics [5, 1137–1143 (2018)]，本科生彭昌南、李嘉宇为论文的共同第一作者；基于光学缝隙天线的偏振编码亚波长全光逻辑门的研究工作发表在Nanoscale [10, 4523–4527 (2018)]，本科生杨子宸、傅杨为论文的共同第一作者。上述工作为物理学院的本科生拔尖人才培养做出了突出贡献，在此过程中，中心教师本身也获得了可喜的提升，例如，在物理学院职称晋升的激烈竞争中，青年教师李智和廖慧敏于 2017 年分别晋升为教授和副教授。

Ⅱ. Progress and achievement in research

The Teaching Center for Experimental Physics has promoted the team building and course construction with the idea of "leading experiment teaching by scientific research". We encouraged teachers to apply for research projects, and gave necessary supporting funds. We also encouraged teachers to introduce research progresses to basic physics-experiment teaching and to construct research-based teaching platforms. Thus, we could train excellent undergraduate students to develop the ability of scientific research and innovation. These efforts have achieved very good results. In the past two years, under the direction of our teachers, undergraduates as first authors have published research papers in several important international academic journals. For example, the research paper on multi-channel and binary-phase all-optical control with on-chip integrated subwavelength plasmonic waveguides was published in ACS Photonics [5, 1575–1582 (2018)], with undergraduate Wang Yuhan as the first author. The research paper on universal linear-optical logic gate with maximal intensity contrast ratios was published in ACS Photonics [5, 1137–1143 (2018)]. Undergraduates Peng Changnan and Li Jiayu con tributed equally as first authors to the work. The research paper on spin-encoded subwavelength all-optical logic gates based on single-element optical slot nanoantennas was published in Nanoscale [10, 4523–4527 (2018)]. Undergraduates Yang Zichen and Fu Yang contributed equally as first authors to the work. Our works made outstanding contributions to the cultivation of scientific research ability of undergraduates. Meanwhile, our teachers also acquired a development. For instance, the young teachers Li Zhi and Liao Huimin were promoted to professor and associate professor in 2017 in the fierce competition of title promotion.

10 北京大学电子显微镜实验室 Electron Microscopy Laboratory of Peking University

北京大学电镜室始建于 1964 年，创建之初就被定位为北京大学显微分析测试公共平台（第一个校级平台）。1990 年被批准为电子光学与电子显微镜国家重点学科专业实验室。电镜室在半个世纪的发展过程中，得到学校“世行贷款”“211”“985”项目的大力支持，现有大型电镜 12 台，其中透射电镜 6 台，扫描电镜 3 台，聚焦离子束 3 台，实验室单价 40 万元以上的大型设备有 22 台。2015 年电镜室采购了两台国际上先进的球差电镜用于材料科学和一台冷冻电镜用于生命科学，实验室仪器总价值已接近 1.5 亿元，硬件配置和开放环境在国内已处于领先地位。电镜室现有工作人员 11 人，实验室主任俞大鹏院士，学术委员会主任叶恒强院士，高鹏研究员，工程技术系列的老师 8 位。其中，有博士学位的 8 人，高级职称 9 人（含两位教授级高级工程师），平均年龄 44 岁。实验室人员专业背景涉及：物理学，电子学，化学，材料科学和地质学，人员配备合理。

北京大学电子显微镜实验室的两台球差矫正电镜的配置属于国际领先。其中一台是双球差矫正的 FEI-Themis，空间分辨率高达 60pm，配置很齐全，包括 DPC，球差矫正的 Lorentz 模式，多能谱探头，电子能量损失谱等 。另外一台是美国 Nion 公司的 40-200 kV 的带有单色仪的 HERMES，主要特色是能量分辨率高达 6meV（目前 60kV 的最高纪录），并且空间分辨率在 200kV 也高达 60pm，而且高真空系统无污染，高稳定性几乎无样品漂移。此外，电镜室还配置有多种原位样品台，可以在电镜中实现原位的力学、电学、降温、加热、液体池等实验。电镜上也配置有高速率、高灵敏度的相机（Oneview IS, K2 IS），能够高速纪录相变反应，以及对电子束敏感材料成像。

北京大学电子显微镜实验室开展系列仪器研制开发工作，研制开发了阴极荧光大面积均匀成像系统，并在电镜实验室面向全校开放使用；依托国家重大仪器研制项目，研制并完善了光阴极光电子发射特性表征系统，支撑了项目中光阴极研制任务。

Electron Microscope Laboratory (EML) in Peking University is a user facility center, which was founded in 1964. Now EML is equipped with 12 electron microscopes, including 6 transmission electron microscopes (TEMs), 3 scanning electron microscopes (SEMs), 2 Focused Ion Beam microscopes (FIBs) and 1 Helium Ion Microscope. There are two abreactions corrected TEMs for materials science, i.e., High energy resolution spherical aberration correction electron microscope Nion U-HERMES with energy resolution better than 8meV, and FEI Titan Cubed Themis transmission electron microscope with 60 pm in spatial resolution that is equipped with monochromator, double spherical aberration corrector, K2 IS camera, Bruker Super-X EDX detectors and a few in situ TEM holders. Besides, the Zeiss ORION NanoFab He ion microscope, FEI Titan Krios freeze electron microscope and ThermoFisher Helios G4 UX focused ion beam system are also the most advanced electron microscope in the world now. Totally, there are more than 40 large instruments with price more than 400,000 RMB for each. The total value of the instruments is about 150,000,000 RMB. Now there are 11 staffs in the laboratory including 2 academicians of CAS, one 'Youth 1000 Talent Program' fellow. In the staff team, there are 8 with senior professional titles and 9 with a doctor's degree.

Each year, EML provides characterization services for more than 200 research groups in different departments in Peking University, including School of Physics, College of Chemistry and Molecular Engineering, School of Electronic Engineering and Computer science, College of Engineering, College of Environmental Sciences and Engineering, School of Earth and Space Science, School of Life Sciences, Academy for Advanced Interdisciplinary Studies, and Peking University Health Science Center. Every year around 300 people get trained in the EML and after systematic training they can operate the electron microscopes independently. For the advanced users, all the instruments are available 24 hours in 365 days unless they are under service. Typically, EML serves more than 200 Research Fund Projects every year. In the last a few years, there are hundreds of publications that contain data acquired from EML.

一、原子尺度揭示电荷 - 晶格的耦合效应

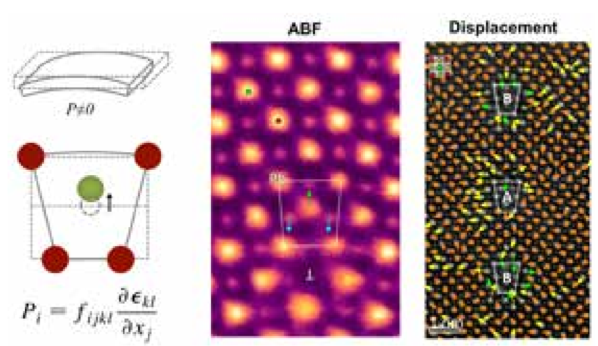
晶体材料的缺陷和表界面区域往往表现与宏观不同的性质，这些性质能够影响甚至主导纳米结构的性能。比如在缺陷处或者材料表面，由于平移对称性发生破缺，总是不可避免地存在应力和应力梯度，由此产生挠曲电效应（Flexoelectric effect，弯电效应）。如图一所示，挠曲电效应是指材料在不均匀的应力下，离子（原子）偏离原来的平衡位置，导致正电荷、负电荷的中心不再重合，从而产生电极化。对于固体中的某个离子而言，不均匀形变改变了周围离子与它之间的距离，从而改变了它们之间的相互作用。因此，这个离子需要发生偏移以到达新的平衡点。在新的平衡点上，离子的正负电荷中心不再重合，从而导致了电极化的产生，这是晶格 - 电荷耦合效应的一种体现。

北京大学电子显微镜实验室的高鹏课题组利用球差矫正透射电子显微镜的环形明场像技术（ABF），精确测量了 $SrTiO_3$ 中的位错 / 小角晶界处由挠曲电效应导致的电极化的大小。研究发现，在位错核附近的两个单胞范围内（约 0.8nm），电极化值大约在 30 μ Ccm^{-2}。

该工作第一次在原子尺度上实现对单个缺陷处的挠曲电效应的直接精确测量，它另外的重要性在于给我们提供了一个全新的视角来看待位错 / 晶界的电活性问题（Electrical activities）。在成熟的位错 / 晶界认知理论中，位错核和晶界处经常存在元素偏析（或产生点缺陷）从而导致位错 / 晶界带有电荷，在它们周围会形成空间电荷区，从而引起背对背的肖特基势垒（或者说能带弯曲），最终会影响甚至决定了这些缺陷的电输运行为。因此，缺陷处的元素偏析一直是陶瓷材料研究的重中之重。但是该工作表明，除了元素偏析，缺陷处的应力与应力梯度的影响同样重要，甚至可能更为重要。文章发表在 Phys.Rev.Lett. 120, 26760 (2018)。

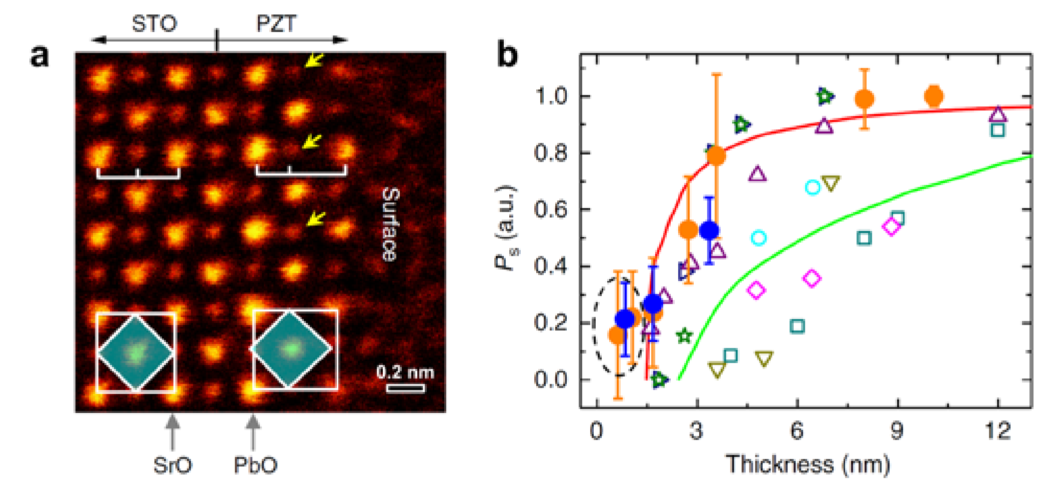
除了缺陷位置的晶格 - 电荷耦合效应，铁电薄膜表面的晶格弛豫对其极化的影响同样引人关注。铁电薄膜在数据储存、传感、表面催化等方面有着许多应用。铁电体的特征就是具有自发的可翻转的电偶极矩。在铁电体的边界处，由于晶体结构平移对称性破缺，从而导致电偶极矩不连续，产生一个与电偶极矩方向相反的退极化场。对于体材料的铁电体，一般不需要考虑屏蔽机制问题，因为边界效应不显著。但是对于小尺寸的铁电薄膜，它的表界面处极化电荷的屏蔽细节就变得非常重要了，屏蔽机制甚至可能决定了整个薄膜器件的物性与应用。

高鹏课题组用定量环形明场像技术精确测量了铁电薄膜中极化强度与厚度的依赖关系。如图二所示，他们在 1.5 个单胞厚度（约 0.6 nm）的钛酸铅薄膜中也发现了稳定的极化 ~16 μ C/cm^2（约为体材料的 17%），这些残留的极化强度主要来自于 Pb 和 O 之间的成键。这是实验上首次观察到的最薄（0.6 nm）的具有铁电极化的钙钛矿薄膜，并且从实验上印证了钙钛矿铁电薄膜中可能并不存在临界尺寸。这些发现为铁电材料的应用提供了重要的信息。研究结果发表在 Nature Communications 8, 15549 (2017)。



图一 . 由于挠曲电效应，应力梯度导致的结构畸变从而产生电极化。（左）原子尺度的挠屈电效应示意图。$SrTiO_3$ 中位错核附近的（中）结构畸变和（右）原子位置偏移。

Figure 1. Owing to the Flexoelectric effect, the structure distortion induced by the strain gradient will produce additional polarization. (left) Schematic of Flexoelectric effect at atomic level. Showing the (center) structure distortion and (right) atom displacement around the dislocation core of $SrTiO_3$.



图二 . (a) 环形明场像的 1.5 u.c. (0.6 nm) PbZr0.2Ti0.8O3 (PZT)/STO 薄膜，使用了伪色以清晰展示各原子。（b）不同薄膜厚度下极化大小的比较，其中蓝色和橙色实心圆点数据来自本工作。

Figure 2. (a) An ABF image of 1.5-unit cells thick PZT on STO. The contrast has been inverted and Pseudo color was applied to the image for clarity. (b) Comparison of the normalized polarization as a function of thickness with previous results. The orange and blue solid discs are from this work.

I. Revealing lattice-charge coupling at atomic scale

Crystalline materials usually contain dislocations and grain boundaries which, reportedly, exhibit a very different nature from the rest of the bulk matrix. The presence of these defects can significantly influence properties such as ionic and electrical conductivities or can even dominate the entire response in nanoscale devices.Owing to the broken translational symmetry at dislocations, a strain gradient naturally exists around the dislocation cores and can significantly influence the electrical and mechanical properties. Because of the strong coupling between lattice and charge (i.e., the electromechanical effects) in these oxides, the presence of strain at the defects is also believed to impact the electrical activity via the piezoelectricity and/or flexoelectricity.

The flexoelectricity is, actually, the strain gradient induced electric dipole moments (as shown in Figure 1), being a property of all insulators, and it can considerably influence the functionalities of materials, particularly for high permittivity materials that have a large flexoelectric coefficient, such as $SrTO_3$（STO） and $BaTiO_3$. For instance, both theoretical and experimental investigations have shown that the mechanical response of ferroelectrics to inhomogeneous strain depends on the polarization orientation because of the flexoelectric effect.

Peng Gao group from the Electron Microscopy Laboratory (EML) of Peking University use aberration corrected scanning transmission electron microscopy to directly observe stable localized electric dipoles exist near the dislocation cores in a 10° small tilt grain boundary of STO bicrystal ((001)/[100]) at room temperature, directly measure the flexoelectric polarization (~ 28 μ Ccm^{-2}) at dislocation cores in STO. The polarization charges can interact with the nonstoichiometric dislocation cores and thus impact the electrical activities.

In this paper, they identify that a localized stable polarized zone exists at the dislocation cores in a 10° STO grain boundary. The point defects, strain field and strain gradient, and nonstoichiometry account for the stable electric dipoles. Their results suggest that the localized polarized zone plays an important role in determining the electrical activities of dislocations and low-angle grain boundaries, as flexoelectric polarization induced bound charge must be screened via a redistribution of free carriers or charged defects. The new insights provided by the localized polarized dislocations can help us to explain some of the past studies, such as the high ionic diffusion barrier along the dislocation cores, and also add more information about the double Schottky barrier model for the low-angle grain boundary in electroceramic STO. Their findings can help us to understand the properties of dislocations in perovskite, providing new insights into the design of new devices via defect engineering such as bi-crystal fabrication and thin film growth. The paper was published at Phys.Rev.Lett. 120, 26760 (2018).

Except to the electromechanical effects around dislocation cores, the effects of interface and surface also become more pronounced when the film becomes thinner. The depolarizing field, which is caused by the incomplete compensation of polarization bound charges at interfaces, mainly account for the size effect and therefore the value of critical size should be much smaller than previous thought (at a few nanometres or tens of nanometres). The depolarizing field increases as the film thickness decreases, leading to the instability of ferroelectricity in the ultrathin films and fine particles.

In Peng Gao group' s study (Figure 2), when the thickness is < 3-unit cells, the similar behavior of suppressed polarization for both of the ultrathin PZT films on insulating substrate and metallic bottom electrode indicates that the compensation of polarization may be governed by the internal screening.

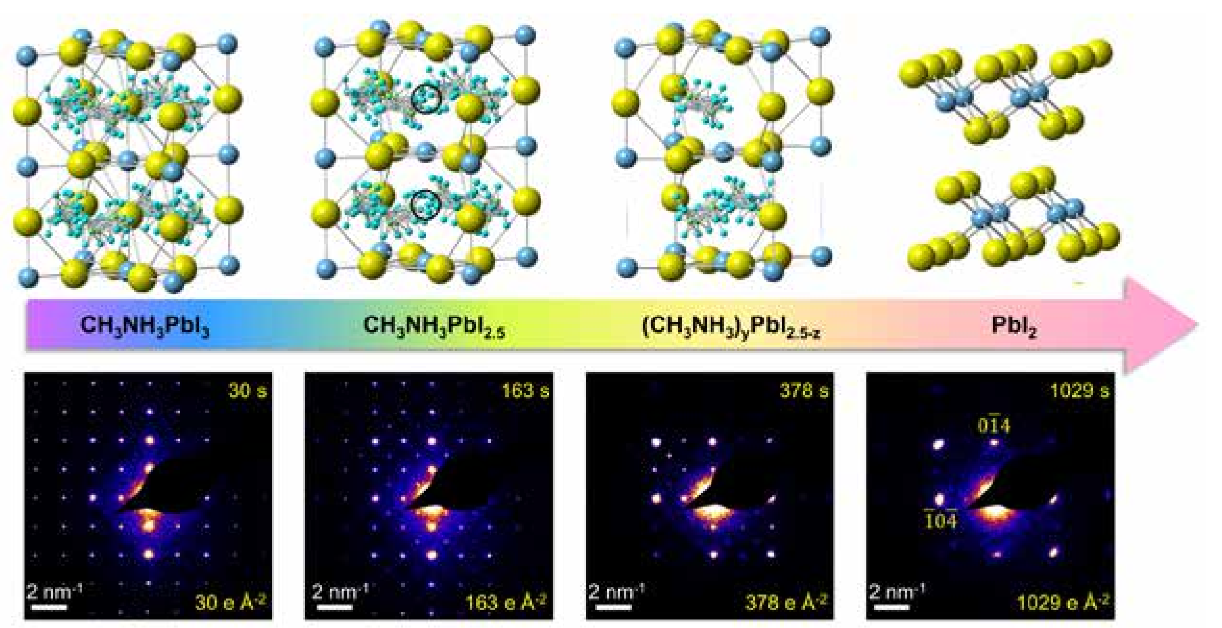
They find that the residual polarization is ~16 μCcm^{-2} (~17%) at 1.5-unit cells (~0.6 nm) thick film on bare SrTiO3. The residual polarization in these ultrathin films is mainly attributed to the robust covalent Pb–O bond. This atomic study provides new insights into mechanistic understanding of nanoscale ferroelectricity and the size effects. This paper was published at Nature Communications 8, 15549 (2017).

二、电子显微学揭示有机无机杂化钙钛矿结构的不稳定性

近年来，由于价格低廉、光电转化效率高，基于有机无机杂化钙钛矿材料 ($CH_3NH_3PI_3$, $MAPbI_3$) 的太阳能电池得到了飞速发展。近十年内，其光电转化效率已从最初的 3.8% 迅速增长至目前的 25.2%。然而，钙钛矿材料在高温、氧气、潮湿、和光照条件下会迅速降解失效，严重阻碍了该材料的产业化发展。研究表明，这些器件在实际工作过程中，外场驱动离子迁移导致其结构退化是器件性能下降和寿命缩短的直接原因。因此，研究钙钛矿材料中离子迁移引起的结构不稳定性和相变过程具有重要意义。

电子显微镜是表征这些有机无机杂化钙钛矿材料的一种常用手段。由于这些材料对电子束敏感，对其原子结构直接成像充满挑战，因此大多数研究者通常采用电子束剂量率相对较低的电子衍射模式进行表征，以此证明材料的钙钛矿物相结构、高质量单晶性质等。然而，诸多文献报道中的实际电子衍射谱图与该材料结构的理论电子衍射谱图存在细微差异，有时理论上应该有的部分衍射点消失或者强度变弱，有时实际图谱中出现不存在的衍射点。这些细微的差异通常被简单忽略掉了，大部分文献仍然把并不精确匹配的电子衍射标定为有机无机杂化钙钛矿材料。

北京大学电子显微镜实验室高鹏研究员，通过严格控制电子束剂量率，研究大单晶 $MAPbI_3$ 的电子衍射标定问题，发现该材料在低电子束剂量下的不稳定性，确定了在电子束辐照条件下避免损伤的阈值条件，进一步提出了相应的分解路径。这些发现对基于电子衍射或者高分辨 FFT 实验数据的解析有着重要意义，纠正了以往电子显微领域内研究者们将碘化铅直接标定成钙钛矿的错误，并强调在未来的电子显微镜研究中应避免该材料分解。该研究中所提出的分解过程及其结构演化路径为我们理解有机无机杂化钙钛矿材料在太阳能电池器件中的结构不稳定性提供了重要信息和理论指导。该项工作发表于 Nature Communications 2018, 9, 4807.



图：钙钛矿在电子束辐照下的分解路径。

Fig. The decomposition pathway of MAPbI3 under electron beam illumination.

II. Electron Microscopy Sheds Light into Decomposition Pathway of Methylammonium Lead Iodide

Organic-inorganic hybrid perovskites ($CH_3NH_3PbI_3$, $MAPbI_3$) are promising candidates for the next-generation solar cells due to their low synthesis cost and rapid increase of device power conversion efficiency from initial 3.8% to most recent 25.2% in less than one decade. Under high temperature, oxygen, moisture and UV light illumination, $MAPbI_3$ decomposes into PbI^2, causing poor long-term stability, which hinders the commercialization of this technology. It is generally believed that the structural degradation, which is caused by the ion migration driven by the external field in the actual working process of these devices, is the direct reason for the performance fading and the shortening of the life for these devices. Therefore, it is of great significance to study the structural instability and phase transition caused by ion migration in perovskite materials.

Electron microscope is widely used to characterize these organic-inorganic hybrid perovskite materials. Since these materials are sensitive to electron beam, electron diffraction mode with relatively low electron-beam dose rates is usually applied to identify the perovskite phase and check the crystallinity. However, there are slight differences between the electron diffraction patterns reported in many literatures from the simulated electron diffraction ones. For example, some theoretical diffraction spots disappear or the intensity becomes weaker, and some reflections that should not appear. These subtle differences are usually simply ignored, and most of the literature still inaccurately identify these mismatched electron diffractions as organic-inorganic hybrid perovskites.

Peng Gao, a researcher in the Electron microscope Laboratory of Peking University, probed the stability of $MAPbI_3$ single crystal films by controlling the electron beam dose rate, and found the instability of the material at low electron beam dose, determined the threshold condition to avoid damage under electron beam irradiation, and proposed the corresponding decomposition pathway. These findings impose important question on the interpretation of experimental data based on electron diffraction, correct the wrong identifications of lead iodide as $MAPbI_3$ in the field of electron microscopy, and highlight the need to circumvent material decomposition in future electron microscopy studies. The structural evolution during decomposition process also sheds light on the structure instability of organic-inorganic hybrid perovskites in solar cell applications. The work was published in Nature Communications 2018, 9807.

11 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 2018 年 12 月，中心已有全职教师 27 人，其中特聘讲席教授 1 人，讲席教授 4 人，教授 8 人，长聘副教授 6 人，预聘副教授 / 助理教授 9 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，2 人当选中国科学院院士，3 人入选中组部“海外高端人才计划”，3 人当选中国教育部“长江学者特聘教授”， 10 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，1 人获北京市杰出青年基金，18 人入选中组部“海外高端人才计划（青年）”，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，目前中心有在站博士后 8 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 154 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、AMO 实验及精密测量、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 16 个独立实验室、1 个综合物性测量公共实验室及 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 (北京大学液氦中心)。

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 2018 年 12 月，中心共发表 SCI 论文近 800 篇，其中多篇发表在 Science、Nature 及其子刊，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 40 余项，科研经费总计超过 3.5 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、国家重点研发计划项目 2 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、华人物理学会亚洲成就奖、求是杰出青年学者奖、马丁伍德爵士中国物理科学奖、国际纯粹与应用物理学联合会青年科学家奖、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 International Center for Quantum Materials (ICQM) was established in 2010 as a major initiative of Peking University, aiming to create a new type of platform for research and education. ICQM has since been committed to perform cutting-edge research at the frontiers of condensed matter physics and quantum materials, to create an innovative academic environment, and to establish a world-class plateform for physics research and education.

As an innovative plateform for science and technology, ICQM has been devoting a great effort to recruit internationally-renowned scientists as well as excellent young researchers, and to provide first-class infrastructure and dynamical scientific environment for basic research. Located in Beijing and amid the fast socioeconomic transformation of China, ICQM endeavors to implement a new academic structure that is based on two major components: independent principle investigator system and tenure appraisal system. As of December 2018, the ICQM faculty members consist of 4 Chair Professors, 8 tenured Full Professors, 6 tenured Associated Professors, and 8 tenure-track Associate/Assistant Professors. Among the senior researchers there are 1 Nobel Laureate, 2 Member of Chinese Academy of Sciences, and 5 Fellows of American Physical Society.

ICQM provides solid training and great research opportunities for young scientists, including postdoctoral researchers and graduate students from both domestic and foreign institutions. In the past a few years, ICQM has hosted 8 postdocs with several of them making important achievements in their research fields. 154 students are currently enrolled in the ICQM graduate program. The ICQM graduate students are typically graduates from top Chinese universities with exceptional academic performances. The students at ICQM are provided with an active scientific environment to explore a wide-range of frontier research topics through a rich array of academic activities, such as seminars, lectures and summer schools.

The research at ICQM is organized into 6 divisions according to research interest and expertise, namely

- Low temperature and quantum transport experiments;
- Spintronics and low-dimensional magnetism experiments;
- High-resolution Spectroscopy experiments;
- AMO experiment and precision measurement;
- Theoretical condensed matter physics;
- Computational physics.

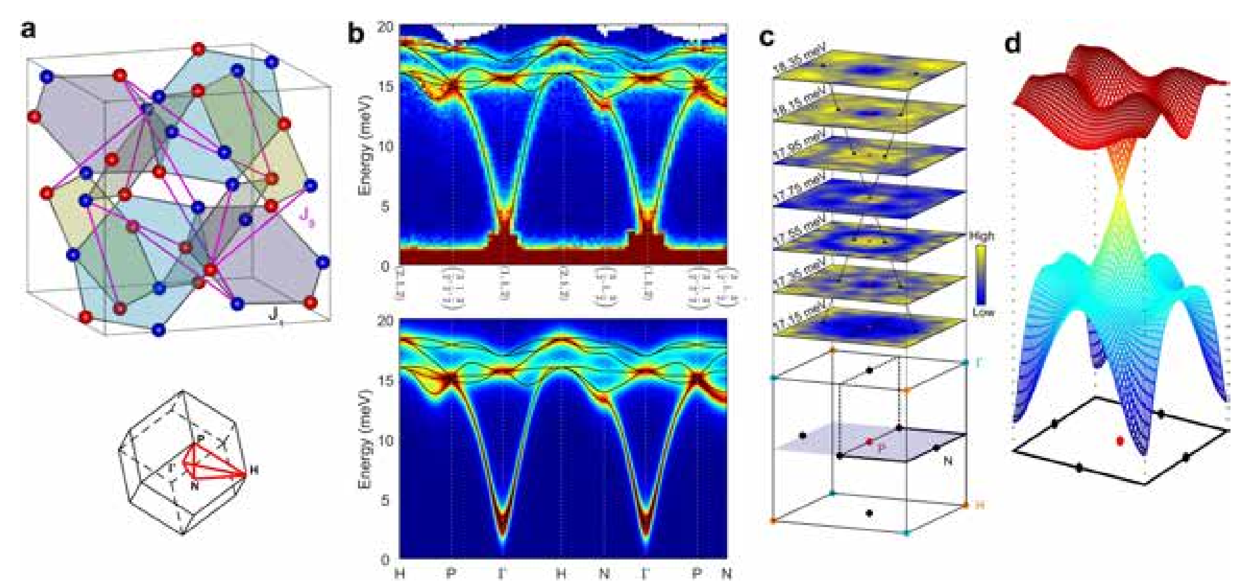
Topics of current research activities include quantum transport, strongly-correlated electron systems, low-dimensional quantum systems, topological effects in condensed matter physics, mesoscopic superconducting systems, spintronics, advanced scanning tunneling microscopy, ultra-fast spectroscopy, neutron spectroscopy, ultra-cold atoms, computational simulations for quantum materials, surface dynamics, water behaviors under confinement, and soft matters materials, etc. ICQM consists of 16 experimental laboratories, a public supporting laboratory for physical property measurement, a shared nanofab facility, and a helium center. The PKU Daniel Chee Tsui laboratory is affiliated to ICQM, which works on extremely low temperature physics.

By December 2018 since the establishment of the center in 2010, ICQM has published nearly 800 SCI papers, 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 350 million RMB. ICQM members have garnered many national and international awards, such as the ACCMS Award, Ho Leung Ho Lee prize, OCPA AAA-Poe Prize, State Natural Science Award, etc.

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

一、三维反铁磁材料中的拓扑自旋波激发

拓扑半金属材料具有拓扑非平庸的电子能带交叠，近年来引起了广泛的研究兴趣。在针对这类受对称性保护的能带交叠现象的研究中，李源课题组考虑了最简单的磁群，即引入了时间 - 空间反演的联合对称性。由此他们预言在三维反铁磁材料中将存在自旋波的拓扑能带交叠，它们在具备和不具备沿某个全局方向的自旋好量子数（或者说，有和没有自旋旋转的 U(1) 对称性）的情形下，将分别呈现出“狄拉克点”和“能带结点线”式的能带交叠。对于一种可以用海森堡模型描述的“自旋网”材料 Cu_3TeO_6，他们使用线性自旋波理论，通过计算得到了狄拉克点型的拓扑能带交点和相应的自旋波表面态 [1]。随后，他们在单晶样品中开展了非弹性中子散射的实验来探测这些拓扑能带交叠。他们发现该材料的自旋晶格具有很高的连接率，这抑制了自旋的量子涨落，从而在实验中获得非常清晰的自旋波信号。实验数据与自旋波理论的结果高度一致，而他们在理论预言中的拓扑能带交叠也得到了直接的实验验证 [2]。



图：a, Cu_3TeO_6 中的磁性 Cu2+ 离子构成的子晶格（上图），其中自旋“上”和“下”的离子分别用红蓝小球表示。下图为体心立方结构的布里渊区。b, 中子散射实验沿布里渊区高对称线测到的自旋波信号（上图）以及相应的理论计算结果（下图），黑细线表示计算得到的色散关系。c, 布里渊区 P 点附近局部的自旋波信号呈现狄拉克锥形的色散关系，这表明体系具有拓扑非平庸的自旋波能带交叠。d, 计算所得的相同位置附近的色散关系（纵轴为能量）。

Figure: a, The sub-lattice of magnetic Cu2+ ions of Cu_3TeO_6 (upper panel), where the up and down spins are represented by blue and red spheres. The lower panel displays the bcc Brillouin zone. b, Magnetic neutron scattering signals along high-symmetry lines of the Brillouin zone (upper panel) in comparison with calculations. Black lines show the calculated dispersions. c, The intensity patterns near the Brillouin-zone P-point indicate local Dirac-point-like dispersions, which evidences the existence of topological band crossing. d, Calculated dispersions near the same region as in c (the vertical axis is energy).

I. Topological magnons in three-dimensional antiferromagnets

The recent discovery of topological semimetals, which possess electron-band crossing with nontrivial topology, has stimulated intense research interest. By extending the notion of symmetry-protected band crossing into one of the simplest magnetic groups, namely by including the symmetry of time-reversal followed by space-inversion, Yuan Li's team predicts the existence of topological magnon-band crossing in a large class of three-dimensional antiferromagnets. The crossing takes on the forms of Dirac points and nodal lines, in the presence and absence, respectively, of the conservation of the total spin along the ordered moments (i.e., spin-rotation U(1) symmetry). In a concrete example of a Heisenberg spin model for a "spin-web" compound, Cu_3TeO_6, Li's team shows the presence of Dirac magnons over a wide parameter range using linear spin-wave theory and calculate the corresponding topological surface states [1]. Inelastic neutron scattering experiments have been carried out to detect the bulk magnon-band crossing in single crystals. The highly interconnected nature of the spin lattice suppresses quantum fluctuations and facilitates their experimental observation, leading to remarkably clean experimental data with very good agreement with their spin-wave calculations. The predicted topological band crossing is confirmed [2].

Related publication and preprint:

[1] K. Li, C. Li, J. Hu, Y. Li and C. Fang, Phys. Rev. Lett. 119, 247202 (2017).

[2] W. Yao et al., arXiv:1711.00632.

二、平衡态拓扑相的非平衡表征理论的建立

如何表征拓扑物相是凝聚态拓扑物相领域最基本的演技课题。基于定义，平衡态拓扑物相由其多粒子基态波函数呈现的拓扑不变量表征。一个基本问题是，对于任意平衡态拓扑相，是否存在一个非平衡的动力学表征？针对此问题，最近北京大学刘雄军组基于一系列工作首次建立起一大类平衡态拓扑物相的非平衡动力学表征理论，并推动相关实验研究的广泛发展（Science Bull. 63, 1385 (2018); Science Adv. 4, eaao4748 (2018); PRL 121, 250403 (2018); Nat. Phys. 15, 911 (2019)）。该系列工作推动形成平衡态拓扑相的非平衡表征理论这一崭新研究方向，对于深入理解拓扑物理以及实验上精确探测拓扑态具有广泛意义。

所建立的非平衡表征理论针对一般的由整数拓扑不变量（高阶陈数或者缠绕数）表征的 d 维费米子拓扑系统。非平衡动力学通过淬火过程实现，方法是突然将系统由拓扑平庸相改变至拓扑非平庸区域，体系的哈密顿量突变导致系统动力学演化。研究发现，尽管系统裸的猝火动力学演化显得很混乱，将动力学演化做时间平均后会在布里渊区中的 (d-1) 维子空间超曲面上—现在被称为"能带反转面"-- 演生出非平凡的拓扑结构。这种演生出的非平衡拓扑结构可由动力学拓扑不变量表征，并与平衡态拓扑相具有普适的对应，从而导致平衡拓扑物相的非平衡动力学表征。这个理论在平衡态拓扑物相和非平衡量子物理之间架起桥梁。一方面，这项工作推动了拓扑物相的表征从平衡态到非平衡态的发展，对拓扑物相的理解具有基本意义，同时提供了全新的拓扑态的非平衡实验探测方法。相比传统的平衡态探测手段，这种动力学探测方案具有众多明显的优势。另一方面，这项工作启发了人们利用拓扑理论来表征复杂的非平衡动力学。例如在淬火过程中即使固定初始和末尾量子物相，仍存有大量不同的淬火方式。对于不同的淬火方式，系统演化表现出显著不同的动力学行为。然而，刘雄军等人的理论告诉我们，这些表面上显著不同的动力学隐含着统一的普适行为：即这些动力学在能带反转面上演生出相同的拓扑模式，因此属于同一拓扑类。这个结论有望对大量复杂的非平衡动力学带来新的理解。

拓扑相非平衡表征理论已经推动了冷原子系统中的众多实验研究。包括已有中国科大，香港科大实验团队和北大理论组合作报导了在一维拓扑相，二维量子反常霍尔体系，以及三维 nodal line 半金属中的应用（PRL 121, 250403(2018)；Science Adv. 4, eaao4748 (2018); PRL 123, 190603 (2019); Nat. Phys. 15, 911 (2019)）。更多的实验研究正在广泛开展中。

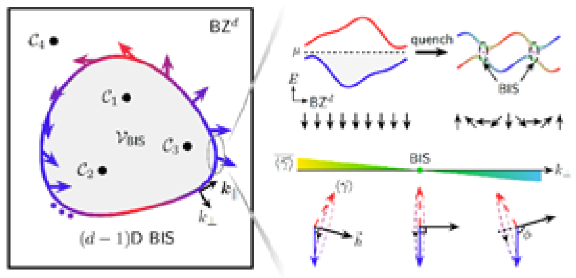


图 1：d- 维平衡态拓扑相的非平衡动力学普适表征。

Fig. 1 Universal dynamical characterization of the d-dimensional topological quantum phases with integer topological invariants.

II. Characterization of equilibrium topological phases by non-equilibrium quantum dynamics

How to characterize a topological phase is a most fundamental issue in the field of topological quantum physics. Conventionally, a topological phase is characterized by a topological invariant defined for a many-particle ground state in equilibrium. A generic question arises, is there a non-equilibrium characterization of a topological phase defined in equilibrium? This non-trivial question was recently proposed and studied through a series of papers by Xiong-Jun Liu' s group at Peking University, who established a non-equilibrium classification theory of equilibrium free-fermion topological phases with integer topological invariants, and bridge equilibrium topological phases and non-equilibrium quantum dynamics. The theory is expected to have broad impact on topological quantum phases, and has pushed forward active experimental studies in this new field. (Refs. Science Bull. 63, 1385 (2018); Science Adv. 4, eaao4748 (2018); PRL 121, 250403 (2018); Nat. Phys. 15, 911 (2019)).

The theory was developed for the generic d-dimensional topological phases, with different phases being distinguished by different integer topological invariants like the winding numbers or Chern numbers. The non-equilibrium dynamics can be induced by quench, in which process one suddenly tunes the system from an initial trivial phase to a final topological regime. The authors found that, while the bare quench dynamics behave randomly, the time-averaged non-equilibrium dynamics exhibit emergent nontrivial topological pattern in the lower (d-1)-dimensional hypersurfaces, dubbed band-inversion surfaces, of the Brillouin zone. Such emergent topological pattern uniquely corresponds to and so characterizes the bulk topology of the equilibrium phase through an emerging dynamical topological invariant, rendering the generic non-equilibrium characterization of equilibrium topological phases. This theory bridges the studies of topological phases and non-equilibrium quantum physics. For one side, the work advances the characterization of topological phases from equilibrium theory to non-equilibrium theory, and provides fundamentally new schemes to detect topological states beyond the equilibrium scenarios. The dynamical schemes show explicit advantages over the conventional equilibrium schemes in the detection of topological states. For another side, the work shows insights into the characterization of complex non-equilibrium quantum dynamics by topology. In condensed matter physics, to characterize non-equilibrium quantum physics is usually more complicated than to characterize equilibrium phases. For example, even fixing the initial and final phases for the quench study, there are numerous paths to perform the quench, and in different quench process the induced bare non-equilibrium quantum dynamics can be sharply different. Importantly, from Liu et al.' s theory all the seemingly distinct quench dynamics manifest identical hidden universal behavior: they exhibit the same emergent nontrivial topological pattern on band inversion surfaces, and so belong to the same topological class.

The proposed theory has already motivated very active experimental studies of the quench dynamics for ultracold atoms. In particular, applications of this theory to 1D symmetry-protected topological phase, 2D quantum anomalous Hall model, and 3D nodal line semimetal have been reported recently (PRL 121, 250403(2018) ; Science Adv. 4, eaao4748 (2018); PRL 123, 190603 (2019); Nat. Phys. 15, 911 (2019)). More experimental studies are ongoing.

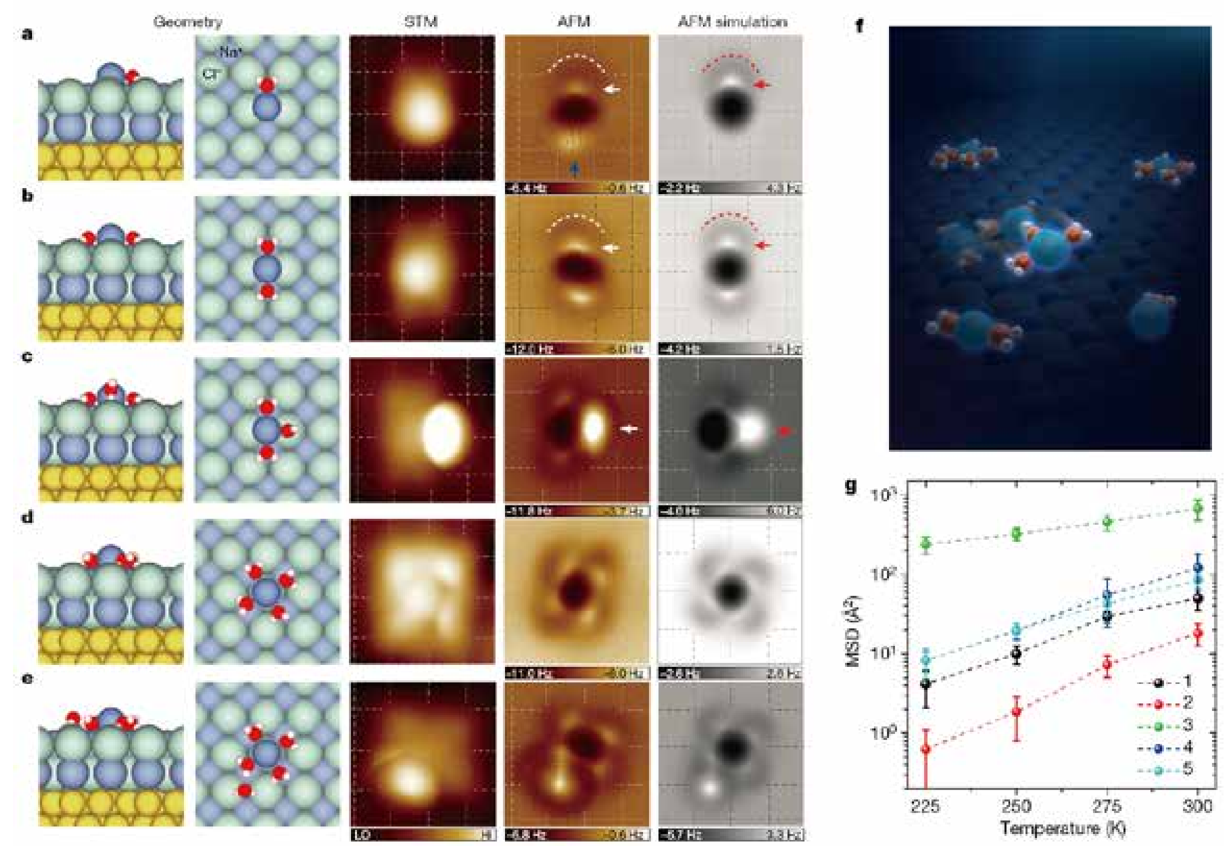
三、首次揭示水合离子的原子结构和幻数效应

量子材料科学中心江颖、徐莉梅、王恩哥组成的联合团队，首次得到了水合钠离子的原子级分辨图像，并发现了一种水合离子输运的幻数效应。该工作于2018年5月14日发表在《自然》，论文链接：https://doi.org/10.1038/s41586-018-0122-2。

水合离子的微观结构和动力学一直是学术界争论的焦点。早在19世纪末，人们就意识到离子水合作用的存在并开始了系统的研究。虽然经过了一百多年的努力，离子的水合壳层数、各个水合层中水分子的数目和构型、水合离子对水氢键结构的影响、决定水合离子输运性质的微观因素等诸多问题，至今仍没有定论。究其原因，关键在于缺乏原子尺度的实验表征手段。

为了突破实验上的瓶颈，江颖等基于扫描隧道显微镜发展了一套独特的离子 / 分子操控技术，在氯化钠表面上可控的人工制备出了单个水合钠离子，水分子的数目精确可调，为高分辨成像创造了条件。在此基础上，他们发展了一套非侵扰式原子力显微镜成像技术（Nat. Commun. 9, 122 (2018)），依靠极其微弱的高阶静电力来成像，克服了针尖对弱键合水合离子的扰动并首次实现了原子级分辨表征，精确确定了其微观吸附构型（图 a-e）。这也是水合离子的概念提出一百多年来，首次在实验中直接“看到”水合离子的原子级图像。进一步，研究人员还发现一种离子输运的幻数效应：包含有特定数目水分子的钠离子水合物具有异常高的扩散能力，迁移率比其他水合物要高 1-2 个量级，甚至远高于体相离子的迁移率。结合第一性原理计算和经典分子动力学模拟，他们发现这种幻数效应来源于离子水合物与表面晶格的对称性匹配程度，而且可以在很大一个温度范围内存在（包括室温）（图 f 和 g）。

该工作首次建立了离子水合物的微观结构和输运性质之间的直接关联，刷新了人们对于受限体系中离子输运的传统认识，对于离子电池、防腐蚀、电化学反应、海水淡化、生物离子通道等相关的应用领域具有重要的潜在意义。该工作入选了“2018年度中国科学十大进展”。



图：a-e, 钠离子水合物的原子级分辨成像。从左至右，依次为五种离子水合物的原子结构图、扫描隧道显微镜图、原子力显微镜图和原子力成像模拟图。图像尺寸：1.5 nm ×1.5 nm。f, 钠离子水合物在 NaCl 表面输运的幻数效应效果图，表明包含 3 个水分子的水合物具有异常强的扩散能力。g, 分子动力学模拟得到的不同离子水合物在 225K-300K 下 1ns 时间内扩散的均方位移。

Figure: a-e, Geometries and high-resolution STM/AFM images of Na^+ hydrates. a-e, The atomic models (left: side view; right: top view), STM/AFM images (acquired with a CO-tip) and AFM simulations of $Na^+ \cdot nD_2O$ clusters (n=1-5), respectively. The size of the images: 1.5 nm ×1.5 nm. f, Schematic showing the magic number effect in the transport of ion hydrates: the Na^+ hydrated with three water molecules diffuses one to two orders of magnitude faster than other Na+ hydrates. g, Mean-square displacement (MSD) in 1 ns of $Na^+ \cdot nH_2O$ (n=1-5) between 225 K and 300 K.

III. Visualizing the atomic structure and magic-number effect of hydrated ions

It is well known that salts will dissolve in the water and the water molecules are bounded with the dissolved ions, forming hydrated ions. The existence of the hydrated ions has already been realized at the end of 19 century. However, many key issues are still under debate so far, such as the water number and configuration in the hydration shells, the effect of hydrated ions on the water structure and dynamics, the microscopic factors that govern the transport of the hydrated ions, and so on. The main reason lies in the lack of experimental tools, which can really "see" and "manipulate" the hydrated ions with atomic precision.

The teams led by Prof. Ying Jiang, Prof. Limei Xu and Prof. Enge Wang of International Center for Quantum Materials (ICQM) of Peking University unravel, for the first time, the microscopic structures of Na+ ion hydrates on the NaCl surface and discover a magic-number effect on the transport of ion hydrate, through a combined study using scanning probe microscope (SPM), density functional theory (DFT) calculations and molecular dynamics (MD) simulations. This work is published in Nature on May 14, 2018 (https://doi.org/10.1038/s41586-018-0122-2).

The researchers figured out a novel method to manipulate individual ions and water molecules by scanning tunneling microscopy (STM). They were able to construct individual Na+ hydrates containing one-to-five water molecules on a NaCl(001) surface, which paves the way for high-resolution imaging of the ion hydrates. Another challenge is to avoid the disturbance of the scanning probes on the ion hydrates, which are highly fragile and flexible. To overcome this difficulty, the researchers developed a weakly-perturbative imaging technique（Nat. Commun. 9, 122 (2018)）, which relies on the weak high-order electrostatic force by noncontact atomic force microscopy (AFM). Such a technique yields the first-ever atomically resolved images of the ion hydrates, in direct comparison with DFT calculations and simulations (Figure a-e).

Furthermore, the researchers found an interesting magic-number effect: the Na+ hydrated with three water molecules diffuses one to two orders of magnitude faster than other Na+ hydrates and even much faster than the Na+ in dilute bulk solution. Ab initio calculations and MD simulations revealed that such high ion mobility arises from the degree of the symmetry match between the hydrate and substrate. The magic-number effect applies within a wide range of temperatures (up to room temperature) according to the classical MD simulations (Figure f and g).

This work established, for the first time, direct correlation between the atomic structure and transport mechanism of hydrated ions, which may completely renovate the traditional understanding of ion transport in nanofluidic systems. In addition, those results point out a new way to control the ion transport in nanofluidic systems by interfacial symmetry engineering, which is of great importance for an extremely wide range of technologically and biologically relevant processes, including corrosion, water desalination, electrochemistry, and biological ion channel, etc.. This work was selected as one of "2018 Top-ten Science Advances in China".

12 北京大学科维理天文与天体物理研究所 Kavli Institute for Astronomy and Astrophysics

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。 研究所近期的高影响力研究成果包括发现宇宙早期发光最亮、中心黑洞质量最大的类星体，发现了有史以来最强的超新星爆发，发现早期宇宙中最大的原初星系团和利用 LAMOST 望远镜发现新的系外行星族群一热海星等。

除了追求科学上的卓越， 研究所也致力于构建中国天文界与国际天文界的桥梁。 研究所 20% 的全职教师、50% 的博士后都是外籍。除了接待来自国内外科研院所的访问学者，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。主要的国际会议包括年度系列会议“星系中的气体”研讨会、“类星体的宇宙学演化”研讨会 和“第二十四届微引力透镜”会议等，研究所也每年举办北京大学科维理论坛，诚邀国内天文科研院校研究人员探讨中国天文未来的发展方向。

研究所现任所长何子山，副所长吴学兵、Gregory J. Herczeg，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。理事会直接向北京大学校长报告工作，以监督研究所的管理运行。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 25 位教师，约 35 名博士后，多名访问学者和 5 位行政人员。

The Kavli Institute for Astronomy and Astrophysics (KIAA) is an international center of excellence in astronomy and astrophysics jointly supported by Peking University and the Kavli Foundation, USA. The KIAA has promoted basic astrophysical research at the frontiers of observational and theoretical fields since start of operations in 2007, with a mission that includes training of undergraduate and graduate students and postdoctoral fellows. 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. Recent high-impact results include discoveries of the most superluminous supernova, the most luminous high-redshift quasar, the largest galaxy cluster at high redshift, and a new group of exoplanets called Hoptunes.

In addition to supporting scientific excellence, KIAA also serves an interface between the Chinese and international astronomy communities; 20% of full-time faculty and 50% of postdoctoral researchers are foreigners, in addition to regular visitors and partnerships between PKU astronomy and a wide network of universities and astronomy centers in China and abroad. KIAA regularly sponsors thematic workshops, conferences, and a range of other academic activities to facilitate scientific exchanges with the domestic and international astronomy community. Major international conferences have included the annual series, "KIAA Forum on Gas in Galaxies", "Cosmic Evolution of Quasars", and an upcoming conference "The 24th International Microlensing Conference". KIAA also regularly hosts the KIAA-PKU Astrophysics Forum, which serves as a platform for the domestic astrophysics community to discuss future directions. English is the working language of the KIAA.

The Institute is under the leadership of its Director Luis C. Ho, Associate Directors X.-B. Wu and Gregory J. Herczeg, 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. A Governing Board, which reports to the President of Peking University, has been established to oversee the management and operations of the Institute. KIAA works closely with the Department of Astronomy, via coordination of research activities, sharing of research facilities and resources, training and supervising of students, and joint participation in the routine operations of the Institute. Together with several joint appointments with the Department of Astronomy and other institutions, KIAA currently has 25 professors, approximately 35 postdoctoral fellows, many visiting scholars, and five administrative staff members.

一、热海星 – 一种可以解决灼热的行星轨道之谜的新型系外行星

迄今为止在宇宙中发现的最令人困惑的行星是“热木星”。这些气态巨行星围绕它们的恒星运行的轨道比太阳系中最内层的行星水星的轨道要近得多。许多天文学家认为，热木星不可能在如此炙热的、与恒星相接的环境下形成，这表明行星在最初形成后，以某种方式向它们的太阳移动。

现在一项新的研究对行星令人困惑的出处提供了新见解，这就是热海星，它就像热木星的小表弟。北京大学科维理研究所由东苏勃领导的团队和南京大学由谢基伟领导的团队发现，这两种行星有着惊人的相似之处。热海星经常围绕着金属丰度更高的恒星运行。热海星也跟热木星一样，存在于单行星太阳系。显然，产生热矮星的过程也可能会产生炽热的、巨大的行星，并指向共同的、最终可知的起源。

“几十年来，了解木星是如何形成的一直是出于探索阶段，而热海星的发现为这一正在进行的研究增添了重要的新线索，”KIAA 的教授东苏勃如是说。“我们的研究表明，热海星很可能是在与热木星类似的条件下形成的，这意味着我们的研究逐步接近灼热行星的形成机制。”

东苏勃用“热海星”这个名字来描述那些拥有地球 2 到 6 倍直径的行星。这个尺寸范围略低于海王星的直径，略高于海王星的直径。海王星的直径为地球的 4 倍，远低于地球直径 9.5 和 11 倍土星和木星。然而，热海星的质量仍然未知，所以天文学家不知道它们是像地球一样的岩石还是像海王星一样大部分都是气体。东不称这类行星为“热海王星”，因为它们中的一些在性质上可能比海王星更接近地球。

这个研究小组首次通过美国国家航空航天局 (NASA) 的外行星搜寻飞船开普勒 (Kepler) 发现了热海星。开普勒通过它们穿过恒星表面时产生的微弱光变发现系外行星。这个研究小组深入研究了开普勒最初发现的一系列近距离行星。为了准确测量行星的大小和恒星中的金属含量，科学家们求助于中国北方的大型多目标光纤光谱望远镜 (LAMOST)。LAMOST 也被称为“郭守敬望远镜”，它使用一种叫做光谱的技术来分离恒星发出的光，揭示恒星的化学组成。光谱学还显示了恒星表面的引力强度——热恒星发出蓝色光芒，冷恒星发出红色光芒——就能显示出它们的大小。LAMOST 可以同时对数千颗恒星进行光谱分析，为天文学家提供海量的关键数据。

“LAMOST 目前是世界上大规模拍摄恒星光谱的效率最高的机器，”东说。“通过 LAMOST，我们能够识别和描述太阳系以及孕育热矮星的恒星。”

热海星和热木星 - 宿主太阳系之间发现的相似性可能支持天文学家完善巨大行星如何形成的理论。以观察到的金属或金属丰度为例，一些天文学家认为更高的金属丰度意味着，在围绕年轻恒星的气体、尘埃盘中，能够形成行星的固体物质数量更多。盘里的物质慢慢粘在一起，形成越来越大的岩石状物体。特别是强引力的大质量天体可以捕获气体的深层大气，形成类木行星，或者海王星或天王星。然而，低金属含量的系统很难产生大行星。

人们普遍认为，巨大的行星需要巨大的固体内核来吸收大量的气体。在离恒星很近的地方，可能没有足够的固体材料来形成如此大体积的内核。因此，热木星和气态的热海星在最初形成后一定会以某种方式向它们的恒星迁移。然而，金属在这种迁移中实际发挥的作用仍不清楚。一种可能性是，金属丰度高的盘可能产生大量的大行星，从而产生剧烈的引力相互作用。这个过程可能会促使一些行星向内迁移。

最后，迁移过程也可能与为什么热海星和热木星通常是各自太阳系中唯一的行星有关。一个大行星的向内运动可以通过引力把其他行星踢出去，只留下一个大的行星。值得注意的是，研究小组还发现，热海星没有热木星那么“孤独”，这可能是因为它们的体积较小，使得它们不太能够驱逐其他行星。

为了进一步揭开行星在其恒星周围紧密轨道上的起源，东和他的同事们期待着不久能有大样本的行星用于研究。“凌日系外行星巡天望远镜”(Transiting Exoplanet Survey Telescope，简称 TESS) 将于 2018 年 3 月发射升空，由麻省理工学院 (MIT) 天体物理与空间研究所领导。该望远镜应该会在距离最近、最亮的恒星周围发现数千颗系外行星。许多行星将处于紧密的轨道上，而且由于距离较近，很容易进行详细的研究。

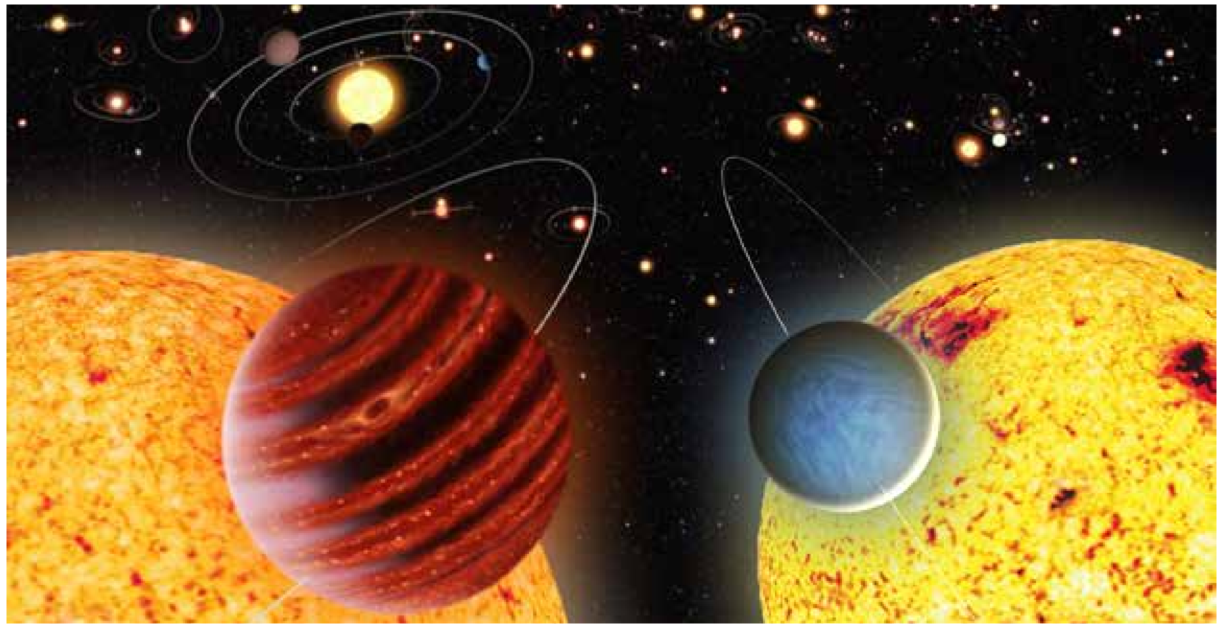
“用 TESS 和其他未来的设备，我们期望找到更多热木星和热海星来用于研究，”东说。“我特别期待通过热海星的高分辨率光谱研究可以得到它们的质量，这可以提供重要的证据来了解这些炙热行星的性质。”

研究团队的其他成员和论文的共同作者是南京大学的周济林，犹他大学的郑正和中国科学院国家天文台的罗阿理。该研究部分由中国国家自然科学基金，中国科学院，中国基础研究重点发展项目和中华人民共和国优秀博士论文作者基金资助。

论文 : http://www.pnas.org/content/115/2/266.full

北大新闻 : http://pkunews.pku.edu.cn/xwzh/2018-01/17/content_301049.htm

系所中心研究亮点 | *Highlights*



在这幅外行星拼贴画中，左侧是艺术家描绘的一个热木星系外行星在一个围绕太阳的紧密轨道上。右侧描绘了一个新发现的系外行星，称为热海星。这些行星的大小从比海王星小一点到大一点不等。就像比他们更大的木星一样，热海星也在近距离灼热的轨道上环绕着他们的恒星。背景显示了太阳系的多样性。（图片来源： 北京天文馆合成图像，使用公共领域和知识共享许可图像。致谢：NASA / ESA / ESO）; Danielle Futselaar 和 Franck Marchis，SETI 研究所 ; NASA / JPL-Caltech; 美国宇航局戈达德太空飞行中心 ; 以及 NASA / SDO）。

In this exoplanetary collage, the left side is an artist's depiction of a hot Jupiter exoplanet in a tight orbit around its host sun. The right side depicts a newly described population of exoplanets, dubbed Hoptunes. These worlds range in size from a bit smaller to a bit larger than Neptune. Like their bigger Jovian cousins, Hoptunes also encircle their stars in close, scorching orbits. The background displays some of the diversity of solar systems. (Credit: Composite image by Jin Ma at the Beijing Planetarium, using public domain and Creative Commons-licensed images with credits belonging to NASA/ESA/ESO; Danielle Futselaar and Franck Marchis, SETI Institute; NASA/JPL-Caltech; NASA's Goddard Space Flight Center; and NASA/SDO)

I. Introducing "Hoptunes", a New Class of Exoplanets that Could Help Solve the Mystery of Worlds in Scorching Orbits

In this exoplanetary collage, the left side is an artist's depiction of a hot Jupiter exoplanet in a tight orbit around its host sun. The right side depicts a newly described population of exoplanets, dubbed Hoptunes. These worlds range in size from a bit smaller to a bit larger than Neptune. Like their bigger Jovian cousins, Hoptunes also encircle their stars in close, scorching orbits. The background displays some of the diversity of solar systems. (Credit: Composite image by Jin Ma at the Beijing Planetarium, using public domain and Creative Commons-licensed images with credits belonging to NASA/ESA/ESO; Danielle Futselaar and Franck Marchis, SETI Institute; NASA/JPL-Caltech; NASA's Goddard Space Flight Center; and NASA/SDO)

Among the most baffling worlds discovered so far in the universe are "hot Jupiters." These gas giants orbit their host stars far closer than the innermost planet in our Solar System, Mercury, orbits the Sun. Many astronomers think hot Jupiters could not have formed in such searing, star-kissed conditions, suggesting the planets somehow moved in toward their suns after initially taking shape.

Now a new study offers fresh insight into the planets' perplexing provenance, thanks to a newly described clutch of toasty worlds—dubbed Hoptunes—that are like hot Jupiters' smaller cousins. Led by Subo Dong of the Kavli Institute for Astronomy and Astrophysics (KIAA) at Peking University and Ji-Wei Xie of Nanjing University, the study finds striking similarities between the two planetary types. Akin to their bigger brethren, Hoptunes often orbit stars with higher abundances of what astronomers call metals—elements heavier than helium. Hoptunes also tend to be loner worlds, again like hot Jupiters, hogging host stars all to themselves in single-planet solar systems.

Evidently, the processes that bring about Hoptunes likely extend to the rise of hot, giant planets, too, pointing to a shared, ultimately knowable origin.

"Understanding how hot Jupiters form has been a detective story for decades, and the discovery of Hoptunes adds important new clues to this ongoing investigation," said Dong, the Youth Qianren Research Professor of astronomy at KIAA. "Our study shows Hoptunes probably develop in similar conditions as hot Jupiters, which means we're zeroing in how those conditions permit scorching planets."

Dong coined the name "Hoptunes" for worlds that possess anywhere from two to six times the diameter of Earth. This size range goes a bit below and above the diameter of the planet Neptune, which has a diameter of four Earths—far less than the 9.5 and 11 Earths, respectively, needed to equal Saturn's and Jupiter's tremendous girths. The masses for Hoptunes remain unknown, however, so astronomers do not know which of them are rocky, like Earth, or mostly gaseous, like Neptune. Thus, Dong opted against broadly calling this planetary class "hot Neptunes," because some of them are likely more terrestrial than Neptunian in character.

The research team first got onto the trail of Hoptunes with Kepler, NASA's exoplanet hunting spacecraft. Kepler detects exoplanets through the slight dimming in starlight they cause when crossing the faces of their host stars.

The team dug deeper into a large set of close-in planets initially spotted by Kepler. In order to accurately measure the planets' sizes and the metal levels in their stars, the scientists turned to the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST), located in northern China. Also known as the Guo Shoujing Telescope, it uses a technique called spectroscopy to break apart the light from stars, revealing their chemical makeup. Spectroscopy also indicates the strength of gravity at the surfaces of stars which, when cross-referenced with their color-coded temperature—hot stars shine blue, cool stars glow red—discloses their sizes. LAMOST can uniquely perform spectroscopy on thousands of stars simultaneously, providing astronomers with huge amounts of critical data.

"LAMOST is currently the world' s most efficient machine in mass-producing stellar spectroscopy," said Dong. "Using LAMOST, we were able to identify and characterize the solar systems and the host stars that harbor Hoptunes."

The similarities discovered between Hoptune- and hot Jupiter-hosting solar systems might support astronomers' working theories for how colossal worlds can form. Take the observed levels of metals, or metallicity, for instance. Some astronomers think higher metallicity means greater amounts of solid material available to form planets in the gassy, dusty disks surrounding young stars. Bit by bit, the materials in the disks glom together, growing into ever larger, rocky bodies. Particularly massive bodies with powerful gravitational pulls can capture deep atmospheres of gases, forming Jupiter-like worlds or, on the smaller side, Neptunes or Uranuses. Systems with low metallicities, however, struggle to generate big planets.

It is generally believed that giant planets need massive, solid cores to build up before they can accrete a large amount of gas. In close quarters to stars, not enough solid materials may be available to build up such suitably bulky cores. Therefore, hot Jupiters and gassy Hoptunes must somehow migrate toward their stars after initially forming. Yet the role that metal levels actually play in this migration remains unclear. One possibility is that disks with high metallicity could give birth to a large number of big planets, fostering violent gravitational interactions. This process might encourage some planets to migrate inward.

Finally, the migration process may also have something to do with why Hoptunes and hot Jupiters are usually the only planets in their respective solar systems. The inward movement of a large world can gravitationally kick out other planets, leaving behind just a single, bullying scorcher. Notably, the team also found that Hoptunes are somewhat less "lonely" than hot Jupiters, probably because their smaller sizes make them generally less capable of expelling their fellow planets.

To further unravel the origins of planets in tight orbits around their stars, Dong and colleagues are looking forward to soon having boatloads of new specimen worlds to study. The Transiting Exoplanet Survey Telescope (TESS), a spacecraft launching in March 2018 and led by the Kavli Institute for Astrophysics and Space Research at the Massachusetts Institute of Technology, should discover thousands of exoplanets around the closest, brightest stars. Many of the planets will be in tight orbits and, being nearby, quite amenable to detailed study.

"With TESS and other upcoming missions, we expect to find a lot more hot Jupiters and Hoptunes to study," said Dong. "I am especially looking forward to high-resolution spectroscopic studies of Hoptunes that could yield their masses, which could provide important evidence to crack the case of these roaster planets."

Other members of the research team and paper co-authors are Ji-Lin Zhou of Nanjing University, Zheng Zheng of the University of Utah, and Ali Luo of the National Astronomical Observatories of the Chinese Academy of Sciences. The research is funded, in part, by the National Natural Science Foundation of China, the Chinese Academy of Sciences, the Key Development Program of Basic Research of China, and the Foundation for the Author of National Excellent Doctoral Dissertation of People’s Republic of China.

Paper: http://www.pnas.org/content/115/2/266.full
PKU News: http://pkunews.pku.edu.cn/xwzh/2018-01/17/content_301049.htm

二、发现早期宇宙中最大的原初星系团

星系团是宇宙中最大的引力束缚结构，它们是研究星系演化和宇宙学的有力工具。在人们已经发现的较成熟星系团中，最遥远的已达 110 亿光年之外（即宇宙学红移 2.5 左右）。近年来，越来越多的工作开始搜寻更遥远的原初星系团，即星系团的前身。这些原初星系团能为研究早期宇宙结构形成和演化提供理想平台。但是，寻找那些极早期、还在形成过程中的大型原初星系团非常困难。根据宇宙学模拟，最大的原初星系团可在其早期形成时期延伸到数十共动兆秒差距，所以必须要足够深和宽场的光谱巡天才能足够可信的认证那些高红移的大尺度结构。

由北京大学科维理天文研究所江林华研究员领衔的国际团队进行了 4 平方度天区的深度光谱巡天，旨在建立一个红移 5.7 左右的均匀莱曼发射星系（LAE）样本。他们观测了五个著名的深场，并在一个称为 SXDS 的深场中发现了一个红移为 5.7 的、巨大的星系高密度天区。随后他们利用光谱观测证实了至少 41 个较亮的莱曼发射线星系。一个巨大的原初星系团（简称 SXDS_gPC）位于该天区的中心区域，尺度约为 353 立方共动兆秒差距（一兆秒差距大约为 3.26 百万光年），其星系空间密度为红移 5.7 处平均密度的 6.6 倍左右。据研究表明，目前还尚未发现在高红移处具有如此大尺度和高密度的原初星系团。江林华团队验证了这样的系统在遥远的宇宙中非常罕见。

SXDS_gPC 的大尺度和高密度远超经典球状引力塌缩理论框架下的塌缩条件，同时，宇宙学数值模拟结果也表明，SXDS_gPC 的结构将不可避免地塌缩成一个巨型星系团。江林华团队采用两种方法估计 SXDS_gPC 塌缩后的质量，包括重子质量和暗物质质量。结果表明 SXDS_gPC 将塌缩成一个质量约为 3.6×10^{15} 太阳质量的星系团。该质量与现已知的、低红移处的最大星系团或者原初星系团质量相似，但远大于所有已知的高红移原初星系团质量。

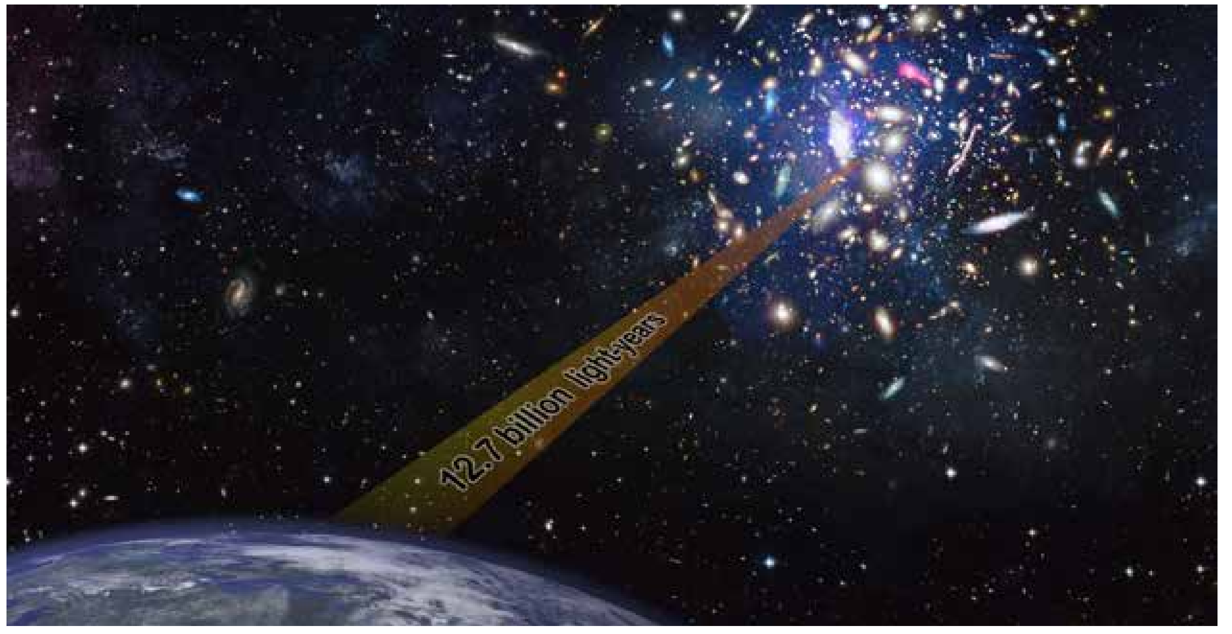


Figure 1: An artist’s conception of a giant protocluster of galaxies in the distant Universe.

冷暗物质宇宙学模型(即现在的标准宇宙模型)预言宇宙中较小的结构通过合并形成更大的结构，也就是说，最大的结构往往形成于宇宙演化的后期。而江林华团队发现的这个巨型原初星系团已经在红移5.7处（127亿光年之外）存在，这相当令人意外。尽管该原初星系团还没有达到引力维里化，但它很高的密度表明该高密度区形成于更早的时期。此类天体将为研究早期宇宙中的结构形成提供一个有力的工具。

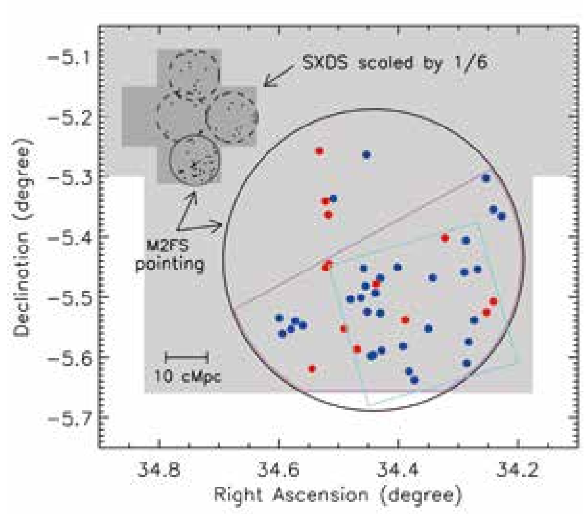
该项研究得到科技部重点研发计划和国家自然科学基金委等项目资助。2018年10月15日，该工作以“A giant protocluster of galaxies at redshift 5.7”为题在线发表在《自然-天文》（Nature Astronomy,2018,DOI:10.1038/s41550-018-0587-9），并被选为当天唯一的高亮（highlight）文章。江林华为文章的第一作者兼通讯作者。

Paper link: https://www.nature.com/articles/s41550-018-0587-9

Nature highlights: https://www.nature.com/articles/d41586-018-07028-2

Nature views: https://www.nature.com/articles/s41550-018-0618-6

PKU News: http://pkunews.pku.edu.cn/xwzh/2018-10/17/content_304633.htm



原初星系团SXDS_gPC的所在天区示意图。蓝点和红点表示已经证实的莱曼发射线星系；青色区域表示SXDS_gPC，它嵌在由洋红色半圆形轮廓勾勒出的大而致密的区域中，其星系密度为平均密度的6.6倍，将塌缩成一个质量约为3.6×1015太阳质量的星系团。

Figure 2: Schematic representation of the SXDS_gPC region. The blue and red solid points represent spectroscopically confirmed, luminous LAEs. The cyan rectangle represents the giant protocluster SXDS_gPC, which is embedded in the large overdense region outlined by the magenta, half-circle-like shape.

II. Discovery of the Largest Protocluster of Galaxies in the Distant Universe

Galaxy clusters trace the largest structures of the Universe and provide ideal laboratories for studying galaxy evolution and cosmology. Protoclusters of galaxies are the progenitors of galaxy clusters. They are a powerful tool for understanding cosmic structure formation in the early Universe. It is, however, very challenging to find the largest protoclusters at early times when they start to assemble. According to cosmological simulations, the largest protoclusters extend over tens of co-moving megaparsecs (cMpc) at the epoch of their early formation, and thus deep, wide-area spectroscopic surveys are needed to reliably identify these giant structures at high redshift.

Jiang and colleagues are carrying out a deep spectroscopic survey of galaxies in four square degrees on the sky, aiming to build a homogeneous sample of Ly α -emitting galaxies (LAEs)at z ≈ 5.7. They are observing five well-studied fields. In one of the fields called SXDS, they identified a large overdense region at z ≈ 5.7. With follow-up spectroscopy, they confirmed at least 41 luminous LAEs. A giant protocluster (SXDS_gPC for short) within a volume of ~ 353cMpc3is embedded in this overdense region. The galaxy density in SXDS_gPCis about 6.6 times the average density at z ≈ 5.7. Protoclusters like SXDS_gPC at high redshift have not been reported before. Jiang’ s team estimated that such systems are very rare in the distant Universe.

The high overdensity of SXDS_gPC well exceeds the collapse threshold in the classical theory of spherical collapse. Cosmological simulations also suggest that an overdense region like SXDS_gPC will inevitably fall into a giant galaxy cluster. Two methods have been used to estimate its present-day mass, which is the total mass of baryonic matter and dark matter in SXDS_gPC. The resultant mass is roughly 3.6 × 10^{15}solar masses, comparable to those of the most massive clusters or protoclusters known to date. This makes SXDS_gPC the most massive protocluster at high redshift.

The cold dark matter model (currently the standard model of cosmology) predicts that small structures merge hierarchically to form large structures. Therefore, larger structures are expected to form in the later cosmic times. The discovery made by Jiang’ s team is remarkable that giant protoclusters like SXDS_gPC already exist when the Universe was only 7% of its current age. Such protoclusters may be ideal probes for understanding early structure formation.

This work is supported by the National Key R&D Program of China and the National Science Foundation of China. The paper was published on Nature Astronomy on Oct. 15, 2018.

Paper link: https://www.nature.com/articles/s41550-018-0587-9

Nature highlights: https://www.nature.com/articles/d41586-018-07028-2

Nature views: https://www.nature.com/articles/s41550-018-0618-6

PKU News: http://pkunews.pku.edu.cn/xwzh/2018-10/17/content_304633.htm

三、脉冲星时间 - 空间框架

大质量恒星演化到晚期，内部聚变燃料耗尽，受到自引力作用，星体将塌缩成直径10km，质量1.4太阳质量左右的中子星。由于质量大而直径小，中子星的自转非常稳定。 中子星中有一部分可以在无线电波段被观测到，其观测现象为周期十分稳定的射电辐射。人们称其为射电天文脉冲星。利用脉冲星稳定的转动特性，人们可以进行精密测量学方面的试验。近年来，大量的研究表明，有望通过多颗脉冲星的观测实现高精度的时间标准建立深空坐标框架。

李柯伽的研究团组深入地研究了利用脉冲星实现时间标准和空间坐标框架的方法。脉冲星时间方面，他们实现了对脉冲星时间 - 原子钟时间差的测量和外推的Bayes算法，并利用欧洲脉冲星测时阵列观测数据对这个算法进行了检验。利用国际脉冲星测时阵列实际数据可以证明，脉冲星在年量级之上可提供比目前使用的原子钟系统更为稳定的时间频率标准。他们在Bayes估计基础上进而研究时间标准中的非平稳过程，即钟跳变问题。利用云南天文台实际观测数据证明， 40米口径的望远镜即

可以实现与 GPS 接收机相当的钟跳变测量精度。

李柯伽的研究团组研究了利用脉冲星形成空间坐标框架的方法。为了构造适宜深空探索使用的坐标框架，需要研究太阳系高精度动力学模型。研究团组利用解析理论探索了脉冲星测时研究太阳系动力学的可能性（Guo et al., 2018 MNRAS）。这个工作表明可以利用脉冲星测时数据来直接探测太阳系中的未知轨道的天体。研究团组结合欧洲脉冲星测时阵列数据（Caballero et al.,2018 MNRAS) 直接测量了太阳系中 8 大行星和若干高质量的小行星的质量。质量的测量结果和 IAU 目前采用的结果是相符合的。这些工作被国际脉冲星测时阵列工作组采用并在第二轮数据发布中给予多次引用，还在 2019 年的《天文学年度综述》（ARA&A）中被多次引用。

针对建立坐标框架研究团组构造了完整的太阳系数值动力学模型。太阳系动力学数值模型描述的是太阳系中行星每时每刻的具体位置和速度。但是长期以来，能够提供高精度星历表的两个单位是美国的 JPL 和法国的 IMCEE。研究团组打破这两个单位的垄断，独立发展了自主的太阳系动力学模型。通过比较 JPL 的数据，目前开发的太阳系动力学模型与 JPL 的计算误差为厘米级（Guo et al., 2018 MNRAS），已经满足构造太阳系坐标框架的需求。

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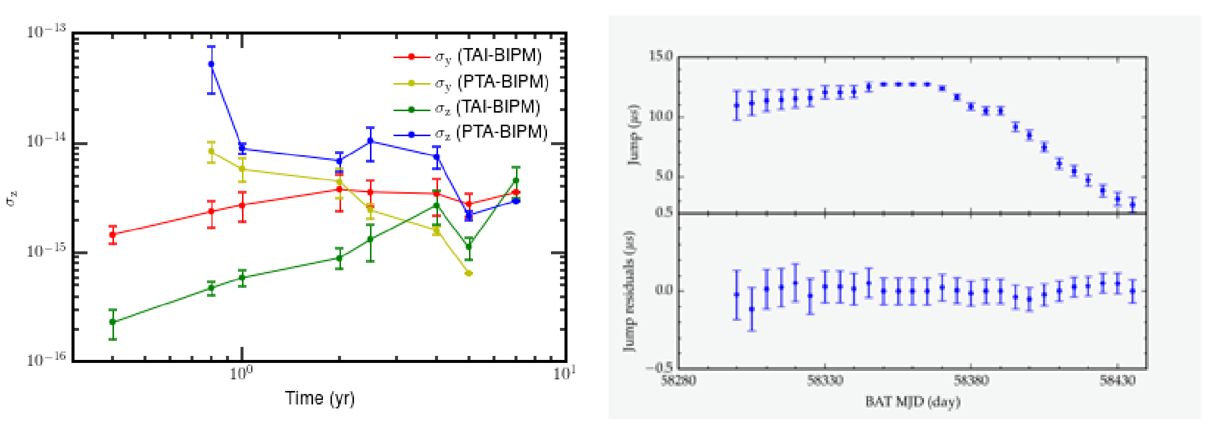


图一、左：构造的脉冲星时间标准与国际原子时之间的比较（Hobbs et al., 2019，MNRAS）。右：利用脉冲星测时改正本地原子钟跳变（Li et al., 2019, SCPMA）

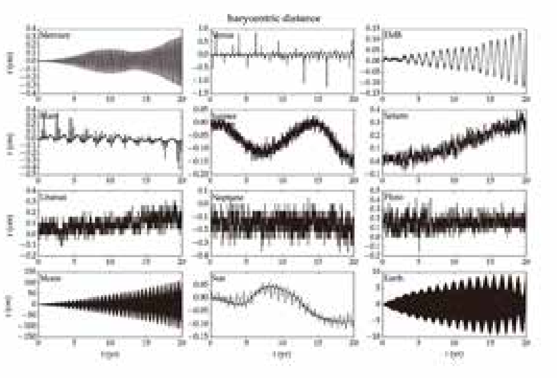
Figure 1. Left：Comparison between international atomic clock standard and pulsar time scale（Hobbs et al., 2019，MNRAS）。Right:Measuring clock jumps using pulsar timing（Li et al., 2019, SCPMA）

III. Pulsar Space-Time reference frame

At the final stage of massive star, its fusion fuel runs out and the core of the star collapse to a neutron star, which has 10 km radius and 1.4 solar mass. Due to the compactness and high mass, the rotation of neutron star is highly stable. A fraction of neutron star can be detected in the radio band, where radio pulses with very regular period were observed. Such stars are named as pulsars. Scientists can carry out high precision metrology experiment with radio pulsars. Recently, large amount works indicate that it is possible to construct long-termly stable clock ensemble and deep-space reference frame by observing multiple pulsars.

Kejia Lee' s research group studied the details of technology to realize the pulsar clock and pulsar reference frame. The Bayesian algorithm in the clock correction inference between the pulsar and ground-based atomic clock is developed. The algorithm is also capable to extrapolate. Using European pulsar timing array data, capability of the algorithm is demonstrated. They also joined the international pulsar timing array collaboration, and carried out related research. They show that, over timescale longer than years, the pulsar clock is more stable than the current international atomic standard. They could provide better time standard with pulsar timing. They further investigated the nonstationary problem in pulsar clock application, namely the clock jump. Clock jump is seen in atomic clocks, they need to correct it for any practical pulsar timing scale. They demonstrate their new algorithm using data from Yunnan observatory. It shows that using 40m telescope, it is possible to realize GPS-level precision in clock-jump correction.

Lee' s group has also studied the method to create deep-space reference frame using pulsar timing. They have shown that the pulsar timing data can be used to probe the Solar system dynamics (Guo et al., 2018, MNRAS). They can directly measure the orbit and mass of Solar system objects. With the European pulsar timing array data (Caballero et al., 2018, MNRAS), they measured mass of 8 planets and a few major asteroids. The mass measurements agree with IAU value. The results had been adopted in the international pulsar timing array data release 2, and cited by the reviews in Annular Review in Astronomy and Astrophysics. They also developed the high precision solar system dynamic model, which is used to describe the position and velocity of solar-system objects. Before their work, the only two institutes could provide such information, namely JPL of NASA and IMCEE in France. By compare results with JPL model, they show that the model error is at cm-level (Guo et al., 2018 MNRAS), which is adequate for constructing the solar system reference frame.



图二、李柯伽团组的太阳系动力学模型和 JPL DE435 的行星位置比较（Guo et al., 2019, MNRAS）。

Figure 2、Tne comparison between the new solar system dynamic model and JPL DE435（Guo et al., 2019, MNRAS）。

Reference
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13 人工微结构和介观物理国家重点实验室 State Key Laboratory for Artificial Microstructure and Mesoscopic Physics

人工微结构和介观物理国家重点实验室 1990 年经国家计划委员会拨款开始建设，1992 年通过国家教育委员会组织验收通过并正式对外开放。实验室发展的主导思想是：研究时空尺度变化时介观物理新现象及新规律，加强小空间、短时间尺度物理过程理论方法创新和测量手段的发展。注意学科交叉，推动人工微结构和介观物理的研究手段和观念在生命科学、能源以及各种应用学科延伸。面向国家重大战略需求，力争做到既对国家的经济建设和国防建设作出贡献，又要在基础科学的发展上作出贡献。

实验室以《国家中长期科学和技术发展规划纲要》为指导，建设有明显介观物理研究特色、光学与凝聚态紧密结合的研究基地，深入开展介观物理中的重大基础科学问题、应用前沿问题的研究。结合介观物理研究前沿科学问题和所承担的国家重大计划和任务，形成了三个重大研究方向，分别为“介观光学与飞秒光物理”，“介观体系凝聚态物理与器件”和“介观物理交叉与重大应用”。

实验室现在拥有雄厚的创新人才队伍，包括：中科院院士 5 人，长江特聘教授 7 人，国家杰出青年基金获得者 12 人，万人计划 7 人，教育部新世纪 / 跨世纪人才 11 人，国家优秀青年基金获得者 11 人。

实验室有国家基金委创新研究群体 3 个，主持承担了 200 多项国家级科研项目，包括牵头多项国家重点研发计划和重大科学研究计划，以及国家重大科研仪器设备研制专项等。实验室获得 5 项国家自然科学奖二等奖，以及何梁何利科学与进步奖、教育部一等奖等奖励十多项。获国家技术发明奖二等奖 1 项，中国高等学校十大科技进展 2 项。近 5 年来，承担经费超过 5 亿元，发表 SCI 论文 800 余篇，其中，有 8 篇刊登于 Nature（2 篇）和 Science（6 篇）；授权专利 50 余件。

State key Laboratory for Artificial Microstructure and Mesoscopic Physics was built in the year 1990, and was supported by the State Planning Commission. In 1992, our Laboratory passed the evaluation of the State Education Commission and started to run. The guideline for our Laboratory is to investigate the new phenomena and new laws of mesoscopic physics when the matters changes spatially and temporally, and we aim to strengthen the development of theoretical methods and the measurement of physical processes in ultrasmall space and ultrashort time scale. Paying attention to the intersection of disciplines, we develop the research methods and built the concepts to promote the artificial microstructure and mesoscopic physics in life sciences, energy, and various applied disciplines. Our Lab aims to facing the country's major strategic needs, and strive to contribute to the country's economic construction and national defense construction, but also makes the significant contribution to the development of basic science.

Guided by the Outline of the National Medium- and Long-Term Science and Technology Development Plan, the laboratory builds a research basement with the Mesoscopic physical research features and the close integration of optics and condensed matter, and in-depth development of major basic scientific issues and application frontiers in mesoscopic physics. Combined with the frontier scientific issues of mesoscopic physics research and the major national plans and tasks undertaken, three major research directions have been formed, namely, “Mesoscopic optics and Femtophysics”, “Mesoscopic System Condensed Matter Physics and Devices” and “Mesoscopic physical intersection and major applications”.

The laboratory has a strong team of innovative talents now, including: 5 academicians of the Chinese Academy of Sciences, 7 special professors of the Yangtze River, 12 winners from the China National Funds for Distinguished Young Scientists, 7 winners from the National special support program for high-level personnel recruitment, 11 winners from the New Century Excellent Talents in University,4 Young Yangtze Scholar and 11 winners from the National Natural Science Foundation of China Youth Fund.

The laboratory has 3 innovative research groups of the National Fund supported by NSFC, and has undertaken more than 200 national-level scientific research projects in the past five years, including the national key research and development plans and major scientific research plans and special national research equipment development projects. The laboratory won the second prize of 5 National Natural Science Awards, as well as more than 10 awards such as He Liang He Li Science and Progress Award and the first prize of the Ministry of Education, the second prize of the National Technology Invention Award in 2018，two awards on the top-ten-scientific and technological advances in Chinese university of science and technology. In the past five years, the laboratory has funded more than 500 million yuan and published more than 800 SCI papers. Among them, 8 articles were published in the leading journals, i.e., Nature (2 articles) and Science (6 articles); more than 50 patents were granted.

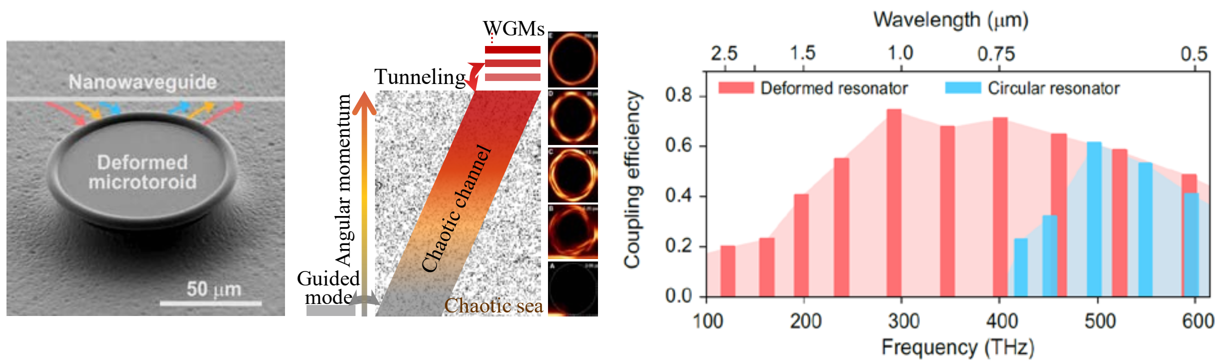
一、混沌光学微腔中的动量转换

动量守恒是自然界中最普遍的客观规律之一，反映了时空性质。大到宇宙星系运动，小到质子、电子或光子等基本粒子间的相互作用，一个封闭系统的广义动量总是保持不变。例如，光子在不同光学结构之间的耦合过程必须遵循动量守恒定律，但由此限制了诸多重要的光子学应用。回音壁光学微腔利用光在介质微腔壁上的全内反射相干叠加形成谐振模式，可以将光子长时间局域在很小的空间内。但是传统的光学微腔具有旋转对称性，光子在其中传输的角动量保持不变，这限制了广泛需求的宽带光子器件应用。

北京大学物理学院肖云峰教授和龚旗煌院士领导的研究小组提出了特定形状设计的非对称微腔可以通过支持混沌运输通道来实现光子动量的转换，进而实现混沌光子的宽带动量转换。借助动力学隧穿过程，混沌运输通道可以在皮秒时间内实现光子动量的转换，连接外部耦合器件和高品质因子的回音壁模式。仿真中验证该过程可以帮助实现纳米光纤和微腔在可见到红外波段（500 纳米至 2900 纳米）均能实现有效的耦合。实验上，他们使用非对称的微盘腔和纳米光纤波导作为实验平台，从可见到红外波段证实了该角动量转化耦合过程具有超宽带的特性，该原理也在三次谐波等非线性频率转换实验中得到了重要应用。

混沌辅助的动量转换新机制具有广泛的应用，不仅能为多模激光、级联拉曼激光、光学频率梳等产生重要作用，还可能在集成光子学、光学网络、量子信息处理等领域发挥重要作用。上述研究成果发表在国际顶级期刊《科学》杂志上。

研究论文的共同第一作者是物理学院 2014 届博士毕业生姜雪峰和信息科学技术学院 2014 届本科毕业生邵林博，现分别在圣路易斯华盛顿大学从事博士后研究和哈佛大学攻读博士学位，论文通讯作者为肖云峰研究员。论文合作作者包括圣路易斯华盛顿大学的杨兰教授，哈佛大学的 Marko Loncar 教授，加州理工学院的易煦博士（物理学院 2012 届本科毕业生）和马格德堡大学的 Jan Wiersig 教授等人。该研究工作得到了国家自然科学基金委、科技部、人工微结构和介观物理国家重点实验室、量子物质科学协同创新中心、极端光学协同创新中心等的支持。



左：变形微腔扫描隧道显微镜图；中：混沌辅助动量转换耦合过程示意图；右：纳米光纤与变形 / 圆形微腔耦合效率仿真对比图

Left: SEM image of a deformed microresonator coupled with a nanowaveguide. Middle: Schematic for the chaos-assisted momentum-transformed coupling process. Inset: Short-time snapshots in 3D FDTD simulations of spatial intensity distribution. Right: 3D FDTD simulation showing coupling efficiencies of a deformed (red) and a circular (blue) microresonator coupled with a nanowaveguide.

系所中心研究亮点 | *Highlights*

I. Momentum transformation in a chaotic optical microresonator

The law of momentum conservation is one of the fundamental laws of the nature, which dominates the movements of matters in an isolated system, ranging from galaxies to elementary particles. In optics and photonics, this conservation law regulates many interesting physical processes. Taking optical whispering gallery mode (WGM) microresonator, which confines resonant photon by total internal reflection, for example. Traditional WGM microresonators possess the rotational symmetry, in which the total internal reflection angle, i.e., the angular momentum of a photon in a WGM keeps constant, and thus rule out many desired broadband photonics processes.

To this end, a group led by Prof. Yun-Feng Xiao and Prof. Qihuang Gong from School of Physics at Peking University reports the broadband momentum transformations of chaotic photons in an asymmetric WGM microresonators. A special shaped asymmetric (deformed) microresonator was designed to create chaotic channels that transform momenta of light. Consequently, via dynamic tunneling, such chaotic channels can serve as a liaison to connect light in the external couplers and the high-Q WGMs, by lifting or lowering the angular momenta of light between them in a few picoseconds. As a result, the broadband coupling of light from visible band to near-infrared (500 nm to 2,900 nm) simultaneously between a fiber nanowaveguide and a WGMs microresonator can be achieved, confirmed in full three-dimensional finite-difference-time-domain (3D FDTD) simulation. Experimentally, a nanofiber waveguide coupled with an ultrahigh Q factor deformed microtoroid was used to realize the momentum transformation process, possessing great advantages in nonlinear frequency conversions, such as broadband cascaded Raman laser, third harmonic generation, and frequency comb.

The proposed momentum-transformed scheme could find applications in a great number of fields, including not only multimode lasers, cascaded Raman lasers, and frequency comb generation, but also broadband quantum memories, multiwavelength optical networks, supercontinuum light source, and quantum information processing. The results were published in Science.

Professor Jan Wiersig from Otto-von-Guericke-Universitat Magdeburg, Professor Marko Loncar from Harvard University and Professor Lan Yang from Washington University in St. Louis also contribute to this work.

二、Si 上 GaN 大失配外延生长和缺陷物理

Si 衬底上 GaN 基功率电子材料和器件在新一代移动通信、新一代通用电源、新能源汽车等领域具有重要应用前景，成为当前国际上半导体科学技术领域的研究热点。 Si 衬底上 GaN 基功率电子材料和器件离真正的实用化还存在一定差距，在高质量 GaN 基材料的外延生长和电子器件可靠性等方面仍存在一系列关键科学和技术问题有待解决，主要包括：Si 衬底上大失配异质外延 GaN 的生长动力学机理、应力和缺陷控制、杂质缺陷物性及其调控规律等。

物理学院宽禁带半导体研究中心沈波和杨学林领导的课题组针对以上关键问题开展了系统的研究，在大失配异质外延方法和 C 杂质掺杂机理研究方面取得了重要进展。他们创新提出了大晶格失配诱导应力调控外延新方法，实现了高质量 Si 衬底上 GaN 厚膜及 AlGaN/GaN 异质结构 (Appl. Phys. Lett. 110, 192104 (2017))，进一步发展了异质结构表面 / 界面质量控制方法，有效降低了表面 / 界面粗糙度对电子的散射作用，获得了 Si 衬底上高质量的 InAl(Ga)N/GaN 异质结构 (Appl. Phys. Lett. 110, 172101 (2017))。通过 C 掺杂获得半绝缘 GaN 是当前研制 GaN 基电子器件的主流方法，确定 C 杂质在 GaN 中的晶格位置至关重要。但作为 IV 族元素的 C 在 GaN 中的掺杂机理非常复杂，针对这一问题，他们结合 Si 衬底上 GaN 外延厚膜结构设计，克服了 GaN 强烈的剩余射线带导致的测量难题，通过红外反射光谱和拉曼偏振光谱，首次观察到 GaN 中与 C 有关的两个振动模，并结合第一性原理计算，确认了这两个振动模分别是 C 替代 N 位（即 CN）的平行于 c 轴振动的 A1 模式声子和垂直于 c 轴振动的双重简并的 E 模式声子，同时确定 CN 电荷态为 -1 价。这是国际上首次给出了 C 杂质在 GaN 中替代 N 位的实验证据，解决了该领域长期存在的争议，论文 2018 年发表在 PRL 上 (Phys. Rev. Lett. 121, 145505 (2018))。

上述研究成果受到国际同行的关注，美国 Stanford 大学、MIT、德国 P. Grünberg 研究中心、莱布尼兹研究所等知名学术机构以及台积电等产业部门的同行学者给予了引用和高度评价。英国著名的半导体专业评论期刊《Semiconductor Today》数次给予了报道和评价。相关成果已用于与华为等国内高技术公司进行技术和产品的合作研发。

该工作得到了国家重点研发计划、国家自然科学基金、2011 协同创新中心、人工微结构和介观物理国家重点实验室等项目的资助。

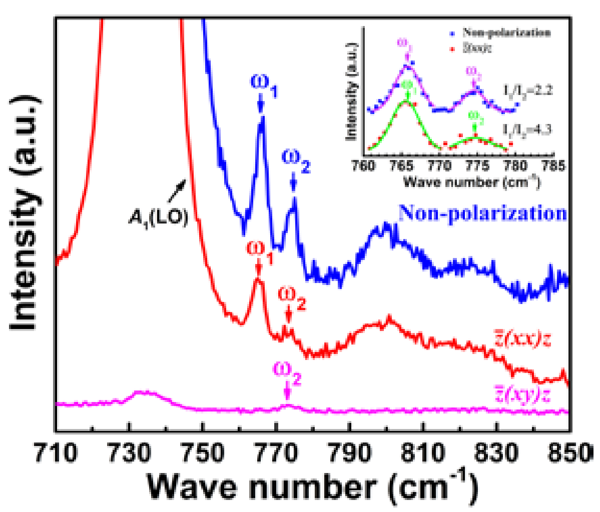


图 1 不同偏振下的拉曼光谱

Fig.1 Polarized Raman spectra.

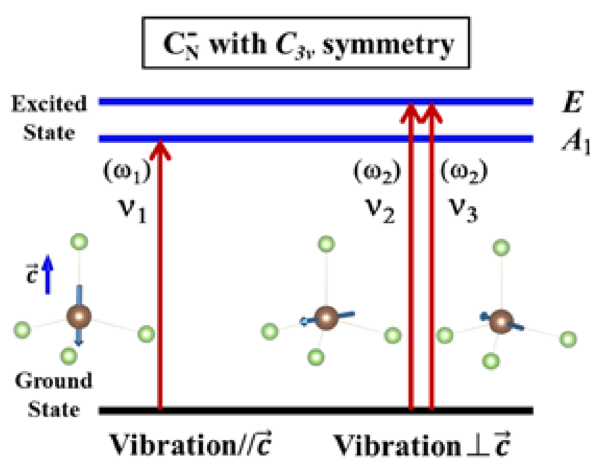


图 2 CN 的两个局域振动模

Fig.2 Two local vibrational modes of CN.

系所中心研究亮点 | *Highlights*

II. Epitaxial growth with large lattice mismatch and defect physics of GaN on Si

GaN based materials and power devices on Si substrates have attracted much attentions due to their promising applications in next generation mobile communications, power supply, and electric vehicles. However, there are several challenges for the material and device reliability including the growth dynamic of heteroepitaxy with large lattice mismatch of GaN on Si, stress and defect control, and the physical properties of impurity/defects and their controlling mechanisms.

Bo Shen and Xuelin Yang’ group at Research Center for Widegap Semiconductor in School of Physics, has deeply studied the heteroepitaxy with large lattice mismatch and the carbon doping mechanism in GaN. They proposed a large lattice-mismatch induced stress control technology and obtained high quality GaN layers and AlGaN/GaN heterostructures on Si substrates (Appl. Phys. Lett. 110, 192104 (2017)). They also developed a novel method to improve the surface/interface quality of the heterostructures and obtained high quality InAlGaN/GaN heterostructures with high mobility at high electron sheet density (Appl. Phys. Lett. 110, 172101 (2017). Carbon (C) doping is of extreme importance for producing semi-insulting GaN which are critical for fabricating GaN based power electronics. Identification of the lattice location of C impurity in GaN is essential for the improvement of device performance. As a group IV element, C is amphoteric in GaN, and the doping mechanism is very complicated. To address this issue, they solved the problem of the strong Reststrahlen-related band by designing the sample structure of thick GaN layers on Si substrate. Two local vibrational modes (LVMs) in C doped GaN were observed for the first time by using polarized Fourier-transform infrared (FTIR) and Raman spectroscopies. By combination with the first-principles calculations, the two LVMs are assigned to the nondegenerate A_1 mode vibrating along the c axis, and the doubly degenerate E mode confined in the plane perpendicular to the c axis, respectively. They are identified to originate from isolated C_N^- with local C_{3v} symmetry. They thus provide an unambiguous evidence of the substitutional C atoms occupying the N site with -1 charge state in GaN and therefore bring essential information to a long-standing controversy. The work was published PRL (Phys. Rev. Lett. 121, 145505 (2018).

The work was highlighted by the international counterparts such as Standford University, MIT, P. Grünberg Institute, Leibniz-Institut fur Kristallzuchtung and TMSC. The work was also reported many times by the famous magazine “Semiconductor Today”. The relevant achievements have been used for cooperative research and development of technologies and products with domestic high-tech companies such as Huawei.

This work was partially supported by the NSFC, the MOST of China, the State Key Laboratory of Artificial Microstructure and Mesoscopic Physics, and Collaborative Innovation Center of Quantum Matter.

15 核物理与核技术国家重点实验室 State Key Laboratory of Nuclear Physics and Technology

北京大学核物理与核技术国家重点实验室于 2007 年经过严格评审由国家科技部批准筹建，2009 年通过验收正式挂牌运行，是我国第一个核科学领域的国家重点实验室。实验室依托粒子物理与原子核物理、核技术及应用、理论物理和高能量密度物理四个学科，其骨干力量主要来自北京大学物理学院技术物理系、重离子物理研究所和理论物理所。依据核科学的国际发展趋势及国家重大战略需求，实验室确定了放射性核束物理、强子物理、先进粒子加速器技术和核技术应用四个研究方向。

实验室现有骨干研究人员 84 人，在站博士后约 20 人，研究生约 200 人。实验室承担科研项目约 120 项，年均外来竞争性科研经费约 6000 万元。实验室拥有 4 台大型加速器设备：2×6 MV 串列静电加速器、4.5 MV 静电加速器、2×1.7 MV 串列加速器，以及 ^{14}C 测量加速器质谱计（AMS），提供粒子束流支撑多学科用户的研究和应用。

实验室开展广泛的国际国内合作，典型的如与日本理化所合办的仁科学校 Nishina School（2008- ）；由美国能源部和中国自然科学基金委支持的中美奇特核理论研究所（CUSTIPEN）；得到国家留学基金委专项资助的 FRIB 博士后学者计划；在欧洲 LHC、日本 RIKEN、美国 ANL 等实施实验研究计划等。

The State Key Laboratory of Nuclear Physics and Technology at Peking University (SKLNPT) is the first state key lab in the nuclear science field in China. The Lab was initially approved in 2007 and formally established in 2009. It mainly consists of the Department of Technical Physics, the Institute of Heavy Ion Physics, the Institute of Theoretical Physics, with disciplines of Particle Physics & Nuclear Physics, Nuclear Technology & Applications, Theoretical Physics, Plasma Physics and High Energy Density Physics. The main research fields of the laboratory include the Hadron physics, Radioactive nuclear beam physics, Accelerator physics and techniques and Nuclear technique applications.

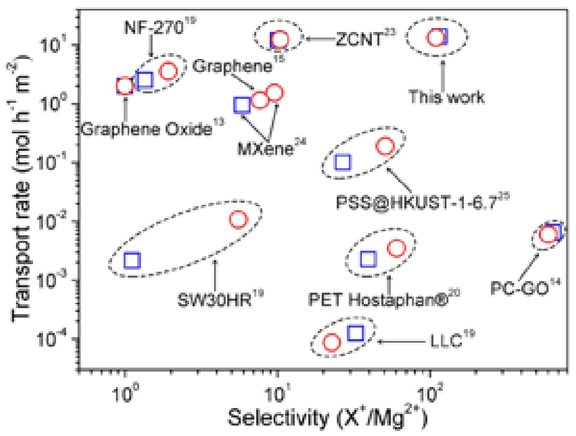
The lab is composed of 84 key researchers, about 20 postdocs and 200 PhD candidate students. About 120 research projects are undertaken by this lab, with an annual budget of about 60 million yuan from the outside funding sources. In addition to carry on basic research experiments at large scale facilities world-wide, the lab provides low energy ion beams for the multidisciplinary research, based on the user facilities, such as the 2 x 6 MV tandem accelerator, the 4.5 MV Van De Graaff accelerator, the 2 x 1.7 MV tandem accelerator and the compact accelerator for ^{14}C AMS.

The lab is operating with broad international and domestic collaborations, of which the representative examples include the Nishina School organized by RIKEN-PKU (since 2008), the CUSTIPEN supported by DOE of US and NSFC of China (since 2013), FRIB fellow program supported by CSC (since 2015), many experimental programs at user facilities in worldwide such as LHC in Europe, RIKEN in Japan, ANL in USA and so on.

一、超高输运通量和高离子选择性的核孔膜

纳米孔道的离子输运现象是材料科学和生物物理等领域研究的热点。当纳米孔道的尺度达到纳米即接近分子大小时，将会出现许多奇异的输运现象。研究这些输运现象对于了解细胞膜离子通道机制，制备新型高效分离设备淡化海水、处理污水，探索新型 DNA 测序方法等都有重要意义。基于核径迹高分子膜制备的纳米孔具有结构坚韧富有柔性并且可以高效大规模制备的优点，但是由于已沿用六十多年的传统化学蚀刻制备法不便可靠控制蚀刻速率，无法接近 1 纳米。

刘峰、王宇钢课题组基于多年来核径迹纳米孔研究工作的基础（JACS，2008,2009；AFM, 2010,2011; EES, 2011 等），首次通过高能重离子轰击高分子膜并进行充分紫外线照射，不进行蚀刻而成功制备亚纳米尺度的核孔膜 （Qi Wen, et al., Advanced Functional Materials，2016, Cover Highlights)。该膜具有超高离子选择性，比如阴阳离子选择性高达 10^8，但导通量离实际应用尚有一定距离。事实上，选择性和通量对于所有分离膜都是一对难以调和的矛盾。通过优选高分子膜并利用新的制备工艺，刘峰、王宇钢课题组所获得的新型纳米尺度核孔膜，在保持碱金属离子与重金属离子高选择性的同时，将离子的输运率提高了 3 个数量级。 这种纳米核孔膜的优异分离性能突破了传统的分离膜和氧化石墨烯等新型分离膜的局限。与此同时，他们还建立了高分子纳米孔模型并通过分子动力学模拟揭示，一方面由于孔的半径在 0.5 纳米左右极大减少了脱水势垒的阻碍从而极大提高了输运量，同时由于部分脱水的离子和表面吸附的电荷之间的相互作用而保持了高选择性。这项研究揭示了纳米孔道的离子输运新机制，并且为突破高选择性和高输运率的矛盾提供了新的思路。通过该方法所制备的高分子膜在过滤重金属元素的水净化，制备新型电池等方面也有重要应用价值。该研究工作以 “Ultrafast ion sieving using nanoporous polymeric membranes ” 为题于 2018 年发表在《自然·通讯》上 (https://www.nature.com/articles/s41467-018-02941-6)。



图、 新型高分子纳米孔膜的输运量和选择性的综合性能超越所有已经报道的其他分离膜。

Figure. Newly fabricated nanoporous polymer membranes show both high permeability and selectivity, outperforming all the other published selective membranes.

I. Track membranes excel in both ionic selectivity and permeability

Ionic sieving with membranes has become the most promising way to achieve large-scale and energy efficient water purification and chemical separations. To fulfill its potential in real applications, it has been a long-standing goal to overcome two great hurdles: permeability/selectivity trade-offs and lack of scalability.

Using the high-energy heavy ion irradiation with HIRFL, Feng Liu and Yugang Wang research group at Peking University succeeded in fabricating nanoporous polymeric membranes with unprecedentedly high permeability and selectivity of cations, outperforming all the other reported membranes in fast ion sieving. The newly developed fabrication process, namely, the track-UV technique, is highly reproducible, and potentially scalable and efficient in industrial-scale production. In their previous work, they fabricated negatively charged subnanometer pores with 12-μm-thick polyethylene terephthalate (PET) Hostaphan® films whose selectivity between alkali metal ions and heavy metal ions is ~10^4 (Wen Qi, et al., Advance Functional Materials, 2016). However, its application is limited because of the low ionic transport rate. In this study, they tested 2-μm-thick PET Lumirror® films with stronger UV absorption and higher irradiation resistance. The nanoporous Lumirror® membranes show highly increased transport rates of alkali metal ions by more than 3 orders of magnitude to about 10 mol h^{-1} m^{-2} without significantly compromising the ionic selectivity. Furthermore, their study reveals the underlying mechanism of the excellent performance of the membranes using molecular dynamics (MD) simulations with a polymeric nanopore model. This more realistic polymeric nanopore model recapitulates the experimental results in the MD simulations, and suggests that ionic selectivity stems from a new transport mechanism operational in an unexplored regime as the sizes of the channels approach the molecular scale. This work was published in Nature Communications in 2018 (https://www.nature.com/articles/s41467-018-02941-6).

二、A-Plot：手性原子核中的角动量取向分布图

对称性和对称性破缺是自然科学中普遍感兴趣的课题。核物理中，自 1997 年 Frauendorf 和孟杰的开创性工作以来 [Nucl. Phys. A 617, 131 (1997)]，手征对称性及其自发破缺引发了大量的实验和理论研究。他们预言，只有原子核的内禀形状显著偏离轴对称椭球，即具有稳定三轴形变时，自发手征对称性破缺才有可能发生。在这些原子核中，由价粒子、价空穴和集体运动组成的原子核总角动量矢量可能位于内禀坐标系的三个主平面之外，从而可以建立左手或右手构型，导致自发手征对称性破缺（如图 1 所示）。内禀系中的手征几何图像，在实验室系中将呈现为一对能量近简并的转动带，即手征双重带。因此，手征双重带的实验观察可以为原子核具有稳定三轴形变提供可靠的直接证据。迄今为止，实验已经至少报道了 50 多对候选的手征双重带 [At. Data Nucl. Data Tables 125, 193 (2019)]。

除了手征双重带的能谱和电磁跃迁等性质，如何描述内禀系中的手性几何是一个重要且有意义的问题。然而，刻画手征几何存在很大的挑战，特别是对角动量投影方法。因为在角动量投影方法中，投影基矢是定义在实验室系下而不是内禀系下

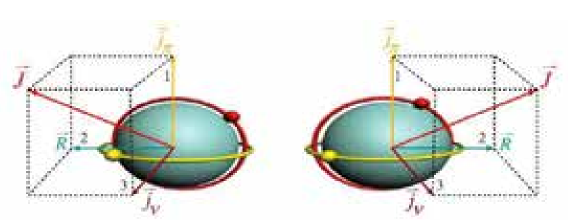


图 1. 原子核中的左手和右手手征几何。

Fig. 1. Left- and right-handed nuclear chiral geometry.

的，而且投影基矢是一套非正交基矢。孟杰研究团队通过选取描述内禀系相对于实验室系取向的欧拉角作为生成坐标，借助该欧拉角与内禀系角动量取向角 (θ, ϕ) 之间的关系，巧妙地克服了这些困难，首次在角动量投影模型和具有组态混合的投影壳模型中刻画了手性原子核的手征几何 [Phys. Rev. C 96, 051303(R) (2017); Physics Letters B 785, 211 (2018)]。通过角动量投影模型计算，图 2 展示了 ^{128}Cs 手征双重带在自旋为 I=11 $\hbar$, 14 $\hbar$和 18 $\hbar$时的角动量方位角图（azimuthal plot），简称 A-Plot。可以看到，在自旋 14 $\hbar$时，手征双重带 A 和 B 的角动量的取向分布相似，呈现非平面取向，展示了静态手性特征；而在自旋 11 $\hbar$和 18 $\hbar$时，带 A 的角动量取向分别呈现出主平面内和主轴分布，静态手性消失。A-Plot 可以清晰呈现手性原子核的手征几何，为深入理解手征对称性提供了重要工具，且有更多的应用前景，如用于研究 wobbling 运动等奇特转动模式。

相关工作发表于 Phys. Rev. C 96, 051303(R) (2017) 和 Physics Letters B 785, 211 (2018)。该项研究得到了国家 973 计划、重点研发计划、国家自然科学基金和博士后科学基金的资助。

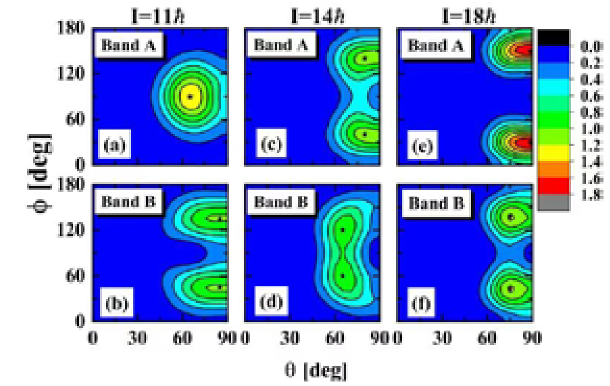


图 2. A-Plot，即原子核角动量在 (θ, ϕ) 平面上的取向分布。图中展示对于原子核 ^{128}Cs 中的手征双重带（带 A 和带 B），角动量投影方法给出的的自旋 I 为 11 $\hbar$ [(a), (b)], 14 $\hbar$ [(c), (d)], 和 18 $\hbar$ [(e), (f)] 时的角动量取向分布。

Fig. 2. Azimuthal plot, i.e., profile for the orientation of the angular momentum on the (θ, ϕ) plane, calculated at I = 11 $\hbar$ [(a), (b)], 14 $\hbar$ [(c), (d)], and 18 $\hbar$ [(e), (f)] for chiral doublet bands (bands A and B) in ^{128}Cs, respectively.

II. A-plot：angular momentum orientation in chiral nucleus

Symmetries and symmetry breaking are a subject of general interest in science. In nuclear physics, chiral symmetry and its spontaneous breaking have stimulated intensive experimental and theoretical studies since the pioneering work by Frauendorf and Meng in 1997 [Nucl. Phys. A 617, 131 (1997)]. The spontaneous chiral symmetry breaking is expected to occur only in an atomic nucleus with an intrinsic shape that substantially deviates from the axial symmetric ellipsoid, i.e., with a triaxially deformed shape. In such specific atomic nuclei, the total nuclear angular momentum vector consisting of valence particles, holes and collective motions may lie outside the three principal planes in the intrinsic frame and form a left-or a right-handed configuration, leading to the spontaneous chiral symmetry breaking. See Fig. 1 for a schematic illustration. The picture of chiral geometry is described in the intrinsic frame, and it is manifested in the laboratory system by the observation of the chiral doublet bands, which therefore provides the sound evidence for triaxial deformation in nuclei. Thus far, more than 50 pairs of candidate chiral doublet bands have been reported experimentally

[At. Data Nucl. Data Tables 125, 193 (2019)].
Apart from energy and electromagnetic transition, it is interesting and helpful to depict the chiral geometry in the intrinsic frame of reference. However, it is a big challenge to examine the chiral geometry, in particular, in the angular momentum projection approach. The reason is that the projected basis is defined in the laboratory frame and forms a nonorthogonal set. The team led by Prof. Jie Meng has overcome these difficulties by treating the Euler angles, which describes the orientation of the intrinsic frame with respect to the laboratory frame, as generator coordinates and by considering the relation between the tilted angles of the angular momentum with respect to the intrinsic frame and the Euler angles. For the first time the chiral geometry is demonstrated in the angular momentum projected states and the projected shell model with configuration mixing [Phys. Rev. C 96, 051303(R) (2017); Physics Letters B 785, 211 (2018)]. Figure 2 shows the azimuthal plots (A-Plots), i.e., the profiles of the angular momentum orientation for the chiral doublet bands in ^{128}Cs for I = 11 $\hbar$, 14 $\hbar$, and 18 $\hbar$. For the partner band A and band B, the angular momenta orientate equally at two directions of aplanar rotation at I = 14 $\hbar$, which demonstrates the occurrence of static chirality. Whereas for band A, the static chirality disappears at 11 $\hbar$ and 18 $\hbar$. Thus, the chiral geometry in the symmetry-restored states is illustrated by the azimuthal plot, which provides a powerful tool to investigate nuclear chirality. Potential applications of the A-plot include many other exotic rotational modes, such as the wobbling motion.
The results were recently published in Journals such as Physical Review C (Rapid Communication) and Physics Letters B. This work was partly supported by the Chinese Major State 973 Program, the National Key R&D Program of China, the National Natural Science Foundation of China, and the China Postdoctoral Science Foundation.

15 北京大学高能物理中心 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，31位国内特聘兼职研究员，6位青年学者，7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, 31 junior fellows and 6 postdocs. The research interests include: cosmology, quantum field theory, particle physics phenomenology and hadronic physics.

一、通过第一原理计算揭示强子内部结构

研究强子（比如质子、中子）的内部结构，对理解强相互作用规律以及我们现实世界的物质构成至关重要。但是对强子结构的理论研究极其困难，在强相互作用基本理论量子色动力学（QCD）提出约40年后的今天，人们依然未能利用QCD计算得到夸克和胶子在质子内部的动量分布函数（PDFs）。近些年，PDFs的第一原理计算方法上有了巨大的突破。

在2013年，季向东教授提出了时间无依赖可用格点QCD计算的quasi-PDFs，并发现，当动量非常大的时候quasi-PDFs可以近似为PDFs。近期，马滟青研究员与合作者把季向东教授的方法进行推广，提出了最一般的方法“格点散射截面”。在该方法中，保留了时间无依赖这一要求，但是与PDFs之间的联系是通过证明因子化定理来保证。马滟青研究员与合作者构造出了一系列便于格点QCD计算的“格点散射截面”，并在量子场论框架下严格证明了它们与PDFs之间联系的因子化定理，从而能够利用格点QCD计算得到PDFs。结果发表在《物理评论快报》上【Phys.Rev.Lett. 120 (2018) 022003】。

此外，在量子场论框架下，quasi-PDFs要想能够用于计算PDFs，它们必须满足紫外发散的可重整性质。马滟青研究员与合作者严格证明了这一性质，这为quasi-PDFs的应用奠定了坚实的理论基础。该结果于2018年9月份投稿，并于2019年初正式发表在《物理评论快报》上【Phys.Rev.Lett. 122 (2019) 062002】。

I. Exploring internal structure of hadrons based on ab initio calculation

Study of the internal structure of hadrons, like the proton or neutron, is crucial to understand both the nature of strong interaction and the constitutive substance of the real world. However, this problem is so hard that, 40 years after the establishment of the fundamental theory of strong interaction, quantum chromodynamics (QCD), one is still unable to calculate parton distribution functions (PDFs) of quarks or gluons inside of the proton based on QCD. Significant breakthroughs of ab initio calculations for PDFs are achieved in recent years.
In 2013, Xiangdong Ji proposed some time-independent quantities, called quasi-PDFs, which can be calculated directly by using lattice QCD. At the same time, it was argued that these quasi-PDFs approach PDFs when momentum is large enough. Recently, Yan-Qing Ma and his collaborator generalized Ji’s idea, and proposed the most general method “lattice cross section”. In this method, the requirement of time independence is retained, but the relation to PDFs is guaranteed by factorization theory. Ma and his collaborator constructed a series of “lattice cross sections” that are convenient for lattice calculation, and proved it rigorously in quantum field theory that these quantities can be related to PDFs via factorization theory. This study makes it possible to rigorously calculate PDFs from lattice QCD. The result is published in Phys.Rev.Lett. 120 (2018) 022003.
Besides, to make it possible to calculate PDFs using quasi-PDFs, a condition is that quasi-PDFs should be multiplicatively renormalizable in quantum field theory. Yan-Qing Ma and his collaborators proved this property rigorously, which is an important theoretical foundation for quasi-PDFs. This result was submitted to PRL in September, 2018, and it was published in early 2019, Phys.Rev.Lett. 122 (2019) 062002.

学生活动
Students

2017 年 9 月 2 日，物理学院组织志愿者参与迎新工作。图为校领导与学院同学老师合影。

On September 2, 2017, the School of Physics organized volunteers to welcome freshmen.

2017 年 9 月 5 日，物理学院在英杰交流中心阳光厅举办 2017 年开学典礼。图为 2017 级班级合影。

On September 5, 2017, the School of Physics held the 2017 opening ceremony.

2017 年 8 月，物理学院 2016 级本科生参加军训。

In August 2017, the 2016 undergraduates participated in military training.

2017 年 9 月，为使新同学融入物理学院大家庭，本科生研究生举行迎新晚会。

In September 2017, the School held an orientation party to help freshmen students integrate into the big family.

2017年10月31日，物理学院举办院长午餐会。物理学院院长与2017级本科新生代表进行了面对面交流，解答同学们对大学生活的困惑。

On October 31, 2017, the School held a dean luncheon. School Dean had a face-to-face communication with the 2017 freshmen representatives to answer the students' confusion about university life.

为了促进学院学生的就业发展，学院每年定期组织企业参访和举行“青藤计划”校友专场招聘会。图为第二届“青藤计划”招聘会。

In order to promote the employment development of students, the School regularly organizes corporate visits and holds "Ivy League" alumni job fairs every year.

2017年12月，物理学院学工办到海南某部队看望学院入伍学生。

In December 2017, the School visited enlisted student in a certain army in Hainan.

2017年12月9日，物理学院物理学院新生代表在北京大学2017年新生“爱乐传习”项目暨纪念“一二·九”运动812周年师生歌会上演唱《星河》，获得了在场观众的热烈掌声。

On December 9, 2017, freshmen representatives from the School performed chorus "Xinghe" at Peking University's 2017 freshman "Philadelphia" project and a memorial event and won rounds of warm applause from the audience .

2017年12月 学院学生自发组织新年晚会，以独具特色的节目迎接新年的到来。

In December 2017, the School students organizeed the New Year's pary.

2018 年 4 月 4 日，物理学院举行春季团校开幕典礼，邀请国家发展研究院李玲教授讲授开学第一课，促进学生骨干全面发展。

On April 4, 2018, the School held the opening ceremony of the Spring Youth League School, and invited Professor Ling Li from the National Development Institute to give the first lesson.

为增强学生的集体凝聚力，相互协作能力，鼓励学生走下网络，走出宿舍，2018 年学院举办第二期“飞跃未名”学生户外素质拓展活动。

In order to enhance students' cohesion and cooperative ability and encourage students to go out of dormitory, the School held the second session of the "Outstanding PKUer" student outdoor development activities.

2018 年 5 月，物理学院举行第七届本科生小型科研项目训练比赛。2018 年 8 月，物理学院学生代表参加第八届中国大学生物理学术竞赛获一等奖。

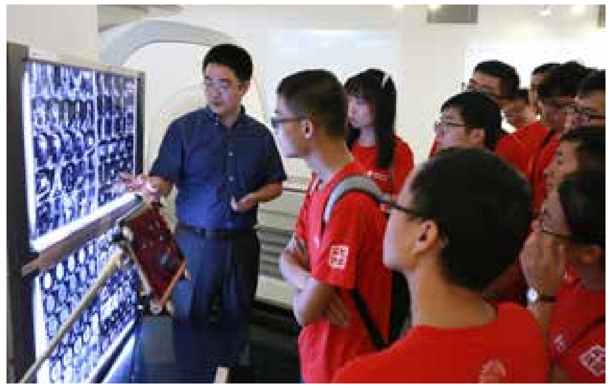
In May 2018, the School held the seventh undergraduate small scientific research project training competition. In August 2018, student representatives won the first prize in the eighth Chinese College Student Physics Academic Competition.

第十五届“北京大学钟盛标物理教育基金”研究生学术论坛成功举办，基金捐赠人钟赐贤先生及夫人夏晓峦女士来校参加颁奖典礼。该学术论坛平均每年参加论坛学生百余人，报名专业涵盖物理学院全部九个学科。

The 15th "Peking University Zhong Shengbiao Physics Education Fund" postgraduate academic forum was successfully held. Mr. Cixian Zhong and his wife, Ms. Xiaoluan Xia, attended the award ceremony. The academic forum has more than 100 students participating every year.

为使学生深入实践，了解国情、社情，学以致用，学院组织多支实践团赴全国各地开展主题为“改革前沿”“科技探路”社会实践。

The School organized a number of groups to carry out social practices on the themes of “frontiers of reform” and “technology exploration” in all parts of the country.



为增强学生身体素质，学生会、研究生会组织同学参加学校新生杯、北大杯、硕博杯、春秋季运动会等体育赛事，策划“动量杯”系列比赛。2018 年院系体育积分排名榜上物理学院以 892 分的成绩位列本部第一名。

In order to enhance students' physical fitness, the students participated in sports events such as the Freshmen's Cup, Peking University Cup, Masters Cup, and the Spring and Autumn Games, and designed a series of "Momentum Cup" games. In 2018, the School ranked first in sports competitions with a score of 892 points.

2018 年 5 月 4 日 物理学院学生代表参加北京大学建校 120 周年庆典活动。

On May 4, 2018, the student representatives participated in the 120th anniversary celebration of Peking University.

物理学院 2017 年毕业典礼在年毕业典礼在英杰交流中心阳光大厅隆重举行，北大物理系 1997 级校友刘文平作为校友代表参加仪式并致辞；物理学院 2018 年毕业典礼在英杰交流中心阳光大厅隆重举行，特邀嘉宾刘诞丽女士为获得“北京市优秀毕业生”荣誉称号的学生颁发证书并合影留念。

The 2017 graduation ceremony was held and the 1997 alumnus Wenping Liu attended the ceremony and delivered a speech. The 2018 graduation ceremony was held and the special guest Ms. Danli Liu presented the certificate to students who have won the honorary title of “Beijing Outstanding Graduates”.

校友与基金
Alumni and Funds

2017 年 10 月 28 日，北京大学物理学院首届校友企业专场招聘会在物理学院思源报告厅举行。校学生就业指导服务中心主任张莉鑫、物理学院党委副书记董晓华，物理学院企业界校友代表及在校师生约 200 人出席了招聘会开幕仪式。

On October 28, 2017, the first alumni enterprise job fair of Peking University School of Physics was held. Lixin Zhang, director of PKU Student Employment Guidance Service Center, Xiaohua Dong, deputy secretary of the School, and about 200 alumni representatives and students attended the opening ceremony.

2017 年 12 月 9 日，物理学院校友会看望深圳校友，举办物理学院“未名湖沙龙”专场，邀请 2000 级本科校友段侪杰、2004 级本科校友郑家新与校友们分享科研成果。

On December 9, 2017, the School visited Shenzhen alumni to hold a special session of the “PKU Salon”, inviting Jijie Duan, a 2000 alumnus and Jiaxin Zhang, a 2004 alumnus, to share their research results.

2018 年 2 月 23 日，学院举办 1983 级本科校友张海云报告会。

On February 23, 2018, the School held a 1983 undergraduate alumnus Haiyun Zhang's report.

2018 年 3 月 10 日，物理学院校友会第七次理事会在物理楼西 113 会议室举行。

On March 10, 2018, the seventh council of the Alumni Association of School of Physics was held.

2018 年，北京大学迎来百廿华诞。此次校庆期间，物理学院共有 53 个年级或班级、1600 余位校友返校聚会，106 位在校生参与到志愿服务中来。学院组织院长报告会，邀请谢心澄院长介绍物理学院近年来学术、科研、人才引进、经费支持等情况；举办校友论坛，邀请了鲍君威、吴双、冯天三位校友分别从无人驾驶、人工智能创业公司管窥、中国芯片制造现状方面与校友们分享工作成果；组织校友舞会，邀请回到学院聚会的校友追忆青春岁月、重温校园时光。

In May, 2018, Peking University celebrated its 100th anniversary. During the school celebration, the School had about 53 grades and classes, more than 1,600 alumni returned to school, and 106 students participating in volunteer service. The School organized dean's report, and invited Dean Xincheng Xie to introduce the academic, research, talent introduction, and financial support of the School in recent years; the School held an alumni forum, and invited Junwei Bao, Shuang Wu, and Tian Feng to share their work; the School also organized an alumni dance party, and invited alumni to gather and relive their campus times.

2018 年 5 月 28 日，物理学院校友会秘书处看望合肥工作校友。

On May 28, 2018, the School visited Hefei Alumni.

2018 年 5 月 30 日，物理学院校友会看望南京大学工作校友。

On May 30, 2018, the School visited alumni working at Nanjing University.

2018 年 5 月 31 日，物理学院校友会看望中电科十四所工作校友。

On May 31, 2018, the School visited alumni of the 14 Institute of China Electronics Technology Corporation.

校友与基金 | *Alumni and Funds*

2018 年 6 月 1 日，物理学院校友会看望浙江大学工作校友。

On June 1, 2018, the School visited the alumni of Zhejiang University.

2018 年 10 月 27 日，北京大学物理学院第二届秋季校友企业专场招聘会在物理学院思源报告厅举行。

On October 27, 2018, the School’s 2nd Autumn Alumni Enterprise Job Fair was held.

校友基金项目：
Alumni Funds:

设立时间 Time of Establishment	项目名称 Project Title	捐赠人 Donators
1987	叶企孙实验物理基金 Qisun Ye Experimental Physics Fund	叶企孙（补发工资），叶先生的友人和学生 Mr. Qisun Ye, his friends and students
1996	谢义炳基金 Yibing Xie Fund	谢义炳先生，谢先生的学生（毛节泰等）Mr. Yibing Xie, his students (Mr. Jietai Mao et al.)
2002	77 物理班级基金（助）'77 Physics Class Fund	北大物理 77 级校友 The '77 physics class
2002	钟盛标物理教育基金 Paul Shin-Piaw Choong Educational Fund for Physics	钟赐贤先生与夫人夏晓峦女士 Mr. Philip Tsi Shien Choong and Ms. Hsia Shaw-lwan Choong
2005	80 物理兰怡女子助学金（助）'80 Ellen Yi Lan Woman Physicist Scholarship	北大物理 80 级校友、兰怡女士的家人和朋友 The '80 physics class, Ms. Yi Lan's family and friends
2005	86 物理班级基金 '86 Physics Class Fund	北大物理 86 级校友 The '86 physics class
2006	88 物理班级基金（助）'88 Physics Class Fund	北大物理 88 级校友 The '88 physics class
2008	陈互雄物理教育基金 Huxiong Chen Educational Fund for Physics	陈敬熊院士与夫人常菊芳女士 Mr. Jingxiong Chen and Ms. Jufang Chang
2008	胡宁奖学金 Ning Hu Scholarship	胡宁家属，秦旦华、苏肇冰夫妇，赵光达等 Mr. Ning Hu's family, Ms. Danhua Qin, the Zhaobing Su couple, and Mr. Guangda Zhao et al.
2010	赵凯华物理教育基金 Kaihua Zhao Educational Fund for Physics	北大校友、师生及相关单位 PKU alumni and concerned departments
2011	求索奖学金 Truth-seeking Scholarship	北大物理 80 级校友汤漪先生与夫人杨洪女士 Mr. Yi Tang and Ms. Hong Yang
2011	张文新教育基金 Wenxin Zhang Educational Fund for Physics	北大物理 49 级校友张文新先生 Mr. Wenxin Zhang
2011	海鸥奖学金 Ou Hai Scholarship	北大物理 78 级校友张兴云先生、樊培女士 Mr. Xingyun Zhang and Ms. Pei Fan
2011	北大物理 91 基金（助）'91 Physics Class Fund	北大物理 91 级校友 The '91 physics class
2011	物理学院学生发展基金 PKU Physics Students Development Fund	北大物理 00 级校友李川、夏英姿、天美等 Mr. Chuan Li, Yingzi Xia, the Tianmei company and et al.
2011	沈克琦物理教育基金 Keqi Shen Educational Fund for Physics	北大物理 88 级校友王多祥先生 Mr. Duoxiang Wang
2012	近代物理研究所奖学金 Institute of Modern Physics Fund	中国科学院近代物理研究所 The Institute of Modern Physics
2012	北大物理 85 念恩奖学金 '85 Physics Class Fund	北大物理 85 级校友（方晶、雷弈安等）The '85 phyics class (Ms. Jing Fang, Mr. Yi'an Lei and et al.)
2013	北大物理紧急救助基金 Emergency Aid for Physics at PKU	北大物理校友、社会各界 PKU physics alumni and community
2013	北大物理新楼报告厅座椅认捐基金 PKU Physics Lecture Hall Chair Donation Fund	北大物理校友、社会各界 PKU physics alumni and community
2013	北大物理 79 级捐赠园林基金 '79 Physics Class Fund for Garden Donation	北大物理 79 级校友 The '79 physics class
2013	北大物理新楼视频会议室基金 PKU Physics Video Meeting Room Fund	北大物理 77 级校友夏廷康 Mr. Tingkang Xia
2013	北大物理新楼楼前花园捐赠基金 Physics Building Front-garden Fund	北大物理 78 级校友胡铭 Mr. Ming Hu
2013	北大物理新楼 7802 会议室基金 PKU Physics 7802 Meeting Room Fund	北大物理 78 级校友 The '78 phyiscs class
2013	北大合伙人基金 PKU Partnership Fund	北大物理 2012 级研究生李骥、宗华、付建波 The '12 physics graduates Ji Li, Hua Zong, and Jianbo Fu
2013	北大 78 级核物理校友奖励基金 '78 Nuclear Physics Class Fund	北大原子核物理 78 级校友（纪力强等）The '78 nuclear physics class (Liqiang Ji et al.)
2013	北大物理兴诚本科生科研基金 PKU Xingcheng Fund	北大技物系 79 级校友 A '79 technical physics alumnus
2014	北大物理 80 校友捐赠基金 '80 Physics Class Fund	北大物理 80 级校友 The '80 physics class
2014	北大物理新楼图书馆新馆阅览室基金 PKU Physics New Liabrary Reading Room Fund	北大物理校友、社会各界 PKU physics alumni and community
2015	北大物理中 212 会议室座椅认捐基金 PKU Physics Buidling 212 Middle Room Chair Donation Fund	北大物理校友、社会各界 PKU physics alumni and community
2015	北大物理津徽学生发展基金 PKU Physics Jinhui Students Development Fund	北大物理 97 级校友王晨扬与夫人程雅女士 Mr. Chenyang Wang and Ms. Ya Cheng
2017	北京大学物理学院发展基金	北大物理校友、社会各界 PKU physics alumni and community
2018	北京大学物理学院锐天明日之星助学金	北京大学物理学院 05 级本科校友徐晓波 / 上海锐天投资管理有限公司
2018	北京大学物理学院锐天明日之星奖学金	北京大学物理学院 05 级本科校友徐晓波 / 上海锐天投资管理有限公司

合作与交流
Exchange & Cooperation

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

2017 年度成功举办“北京大学百年物理讲坛”第十七、十八讲。第十七讲邀请到美国普林斯顿大学教授、2016 年诺贝尔物理奖获得者 F. Duncan M. Haldane 教授做主题演讲并与师生交流。

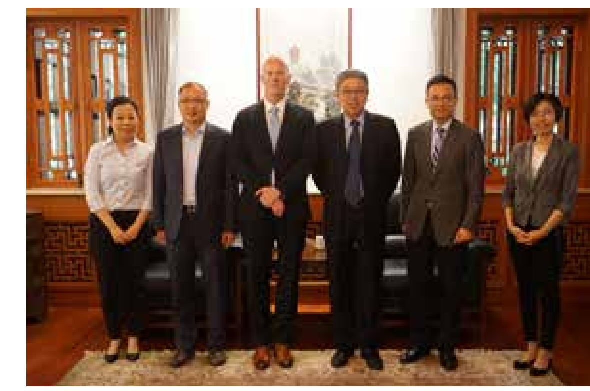
In 2017, the school held the 17^{th} and 18^{th} sessions of The Centennial Physics Lectures. The 17^{th} Lecture was given by the 2016 Nobel Laureate in Physic Prof. F. Duncan M. Haldane from Princeton University.

“北京大学百年物理讲坛”第十八讲邀请到美国国家科学院院士、剑桥大学 Plumian 天文与实验哲学教授 Robert Kennicutt 来校报告访问。

The 18^{th} lecture was given by Prof. Robert Kennicutt, Academician of the American Academy of Sciences and Plumian Professor of Astronomy and Experimental Philosophy at University of Cambridge.

2018 年度成功举办“北京大学百年物理讲坛”第十九、二十、二十一讲。第十九讲邀请到多伦多大学副校长、著名材料学家 Edward Sargent 教授来校报告并与北大师生交流。

We held the 19^{th} to 21th lectures in 2018. The 19^{th} lecture was given by Prof. Edward Sargent, Vice President and worldly noted material scientist.



第二十讲邀请到著名物理学家、美国科学院院士、美国加州大学欧文分校 Wilson Ho 教授来校报告访问。

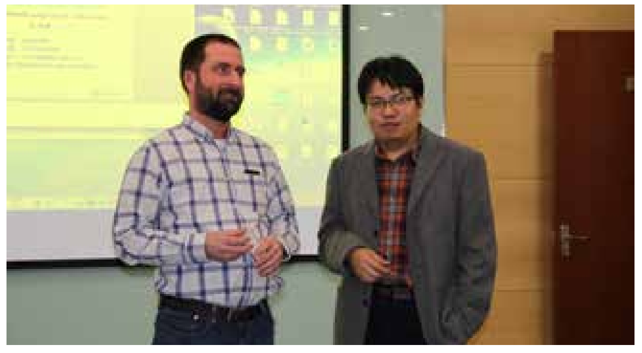
The 20^{th} lecture was given by Prof. Wilson Ho, Academician of the American Academy of Sciences and worldly famous physicist..

第二十一讲邀请到 2018 年诺贝尔物理学奖获得者、法国科学家 Gérard Mourou 教授访问北京大学并发表学术演讲。

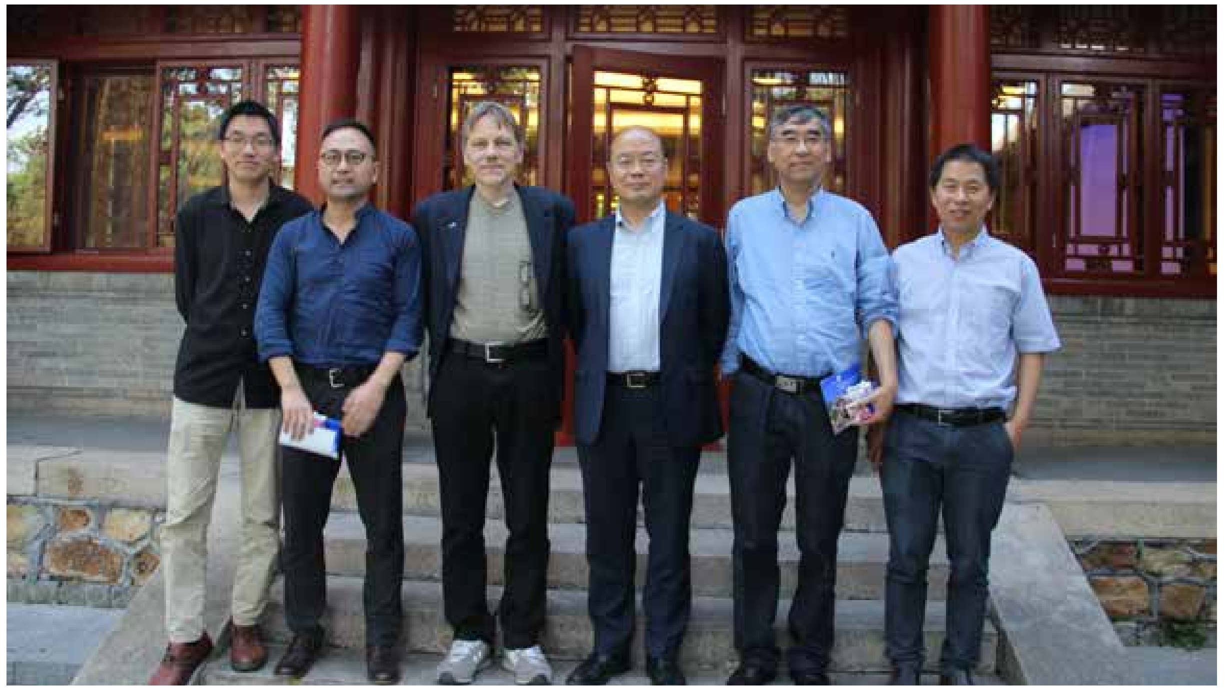
The 21th lecture was given by Prof. Gérard Mourou, the French scientist and the 2018 Noble Laureate in physics.

二、来访接待与学术交流 Exchange Activities

2017 年 1 月，美国林菲尔德学院代表团访问学院，代表团由 2 位教授和 10 名本科生组成，领队是该校的解天宝教授，他是北京大学物理系 64 级校友。物理学院副院长朱守华教授会见了代表团，肖立新教授与到访师生座谈交流。



In January, 2017, a Linfield College delegation of 2 professors and 10 undergraduate students led by Prof. Tianbao Xie, the 1964 PKU physics alumnus, visited the School of Physics. Prof. Shuhua Zhu, Vice Dean of the School of Physics, warmly welcomed the delegation. Prof. Lixin Xiao from School of Physics held a discussion with the delegation.



5 月，德国波恩大学校长 Michael Hoch 访问北京大学，主管国际事务副校长 Stephan Conermann，亥姆霍兹辐射与核物理研究所所长、数学与自然科学学院教授 Ulf Meißner 等人陪同来访。北京大学教务长、副校长高松院士在临湖轩中厅会见了代表团，物理学院副院长胡永云教授等参加会见。其后，来访团与物理学院教师代表亲切座谈，理论物理研究所马伯强教授、现代光学研究所刘运全教授、凝聚态物理与材料物理研究所李新征研究员、技术物理系陈启博博士后和任修磊博士后参加座谈。

In May, a University of Bonn delegation led by Rector Michael Hoch and accompanied by Prof. Ulf Meißner visited Peking University. Academician Song Gao, Provost and Vice President of Peking University, met with the delegation. After the meeting, Rector Hoch and Prof. Meißner attended a discussion with the faculty representatives from the School of Physics: Prof. Yongyun Hu, Associate Dean of School of Physics, Prof. Boqiang Ma from the Institute of Theoretical Physics, Prof. Yunquan Liu from the Institute of Modern Optics, Prof. Xinzheng Li from the Institute of Condensed Matter and Material Physics, Postdocs Qibo Chen and Xiulei Ren from the Department of Technical Physics.

8 月，瑞典皇家理工大学副校长 Stefan Östlund 教授、前副校长 Ramon Wyss 教授、KTH 国际合作部 Yingfang He 女士一行访问北京大学。北京大学副校长、中国科学院院士龚旗煌在中关新园会见了来访客人一行，北京大学国际合作部副部长郑如青，物理学院副院长胡永云，物理学院技术物理系许甫荣等陪同会见。

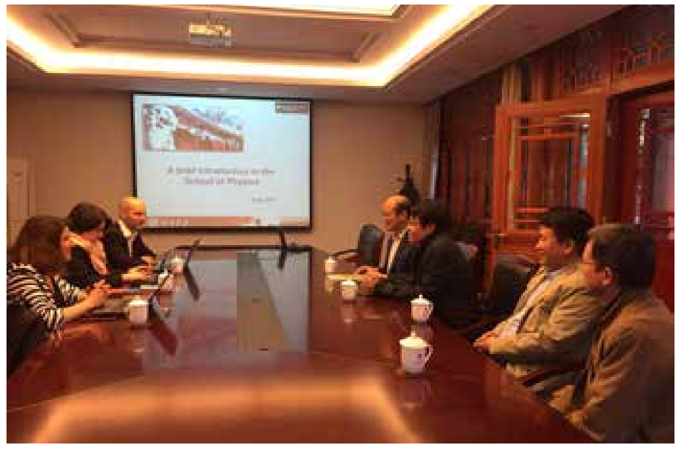
In August, a KTH Royal Institute of Technology delegation led by Vice President Prof. Stefan Östlund, Former Vice President Prof. Ramon Wyss, and Ms. Yingfang He with International Relations visited Peking University. Academician Qihuang Gong, Vice President of Peking University met with the delegation, accompanied by Ruqing Zheng, Associate Director of Office of International Relations at Peking University, Prof. Yongyun Hu, Associate Dean of School of Physics and Prof. Furong Xu from Department of Technical Physics of School of Physics.

9 月，德州大学阿灵顿分校校长 Vistasp Karbhari，副教务长 Pranesh Aswath，物理学院教授 Wei Chan 等一行来访北京大学物理学院。物理学院院长谢心澄，副院长朱守华与来访人员进行了会谈。会后，谢心澄院长陪同来访人员到量子材料中心实验室进行参观。

In September, a University of Texas at Arlington delegation led by President Vistasp Karbhari, accompanied by Vice Provost Pranesh Aswath and Professor in Physics Wei Chan, visited School of Physics. Dean of School of Physics Academician Xincheng Xie and Associate Dean Prof. Shouhua Zhu met with the delegation. After the meeting, President Vistasp Karbhari visited the laboratory of International Center of Quantum Materials accompanied by Dean Xincheng Xie.

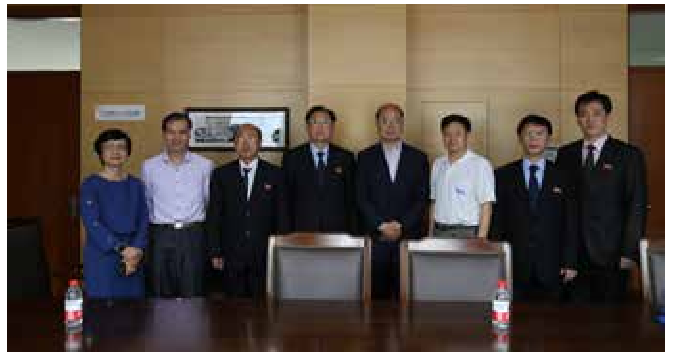
2018 年 4 月，巴黎高科代表团 Ensta ParisTech 外事副主任 Cecile Vigouroux，MINES ParisTech 外事副主任 Alma Catala 和巴黎高科驻华主任 Sylvain Ferrari 访问北京大学，并与物理学院教师代表亲切座谈。座谈会由物理学院胡永云副院长主持，朱守华副院长、技术物理系班勇教授和现代光学研究所吕国伟副教授参加座谈。

In April, 2018, a ParisTech delegation, led by Vice Director of International Relations at ENSTA ParisTech Cecile Vigouroux, Vice Director of international relations at MINES ParisTech Alma Catala and Paris Tech Director of China Relations Sylvain Ferrari visited Peking University and met with the faculty representatives from School of Physics. Associate Dean Prof. Yongyun Hu hosted the meeting. Associate Dean Prof. Shouhua Zhu, Prof. Yong Ban from Department of Technical Physics and Prof. Guowei Lyu from the Institute of Modern Optics participated in the discussion.



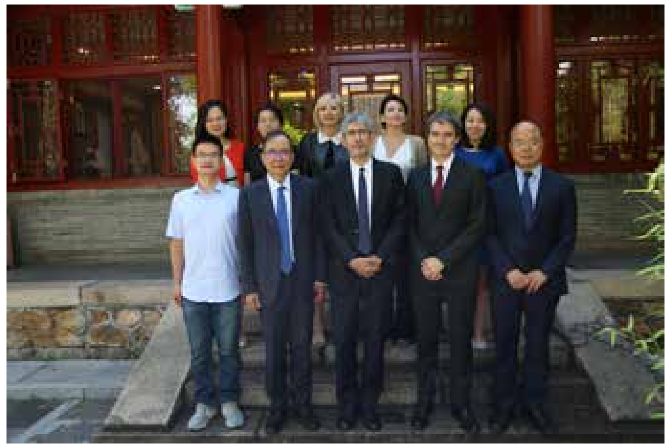
5 月，金日成综合大学校长兼高等教育相 Thae Hyong Chol 代表团在应邀参加北京大学 120 周年校庆之际，对物理学院进行了参观访问。金日成综合大学物理学系主任 Pak Hak Chol，哲学系主任 O Chon Il，外国语文学系中国语言文学课程教师（翻译）Kim Chol Jin 陪同来访。物理学院党委书记陈晓林、副院长胡永云，副书记董晓华、实验教学中心主任张朝晖在物理楼接待了代表团，并举行亲切座谈。会前，金日成综合大学校长代表团在陈晓林书记、张朝晖主任的陪同下参观了北大物理学院实验教学中心。

In May, a Kim Il Sung University Delegation, led by Thae Hyong Chol, President and Minister of Higher Education, visited School of Physics, accompanied by Pak Hak Chol, Dean of the Department of Physics, O Chon Il, Dean of the Department of Philosophy, and Kim Chol Jin, translator and a faculty member of Chinese language and literature. Secretary Xiaolin Chen of School of Physics, Associate Dean Yongyun Hu, Deputy Secretary Xiaohua Dong, and Prof. Zhaohui Zhang, Director at the Experimental Teaching Center met with the delegation. Before the discussion, the delegation visited the Experimental Teaching Center at School of Physics accompanied by Secretary Xiaolin Chen and Director Zhaohui Zhang.



6 月，巴黎萨克莱大学校长 Gilles Bloch，国际发展部部长 Guillaume Garreta 访问北大，法国驻华大使馆高等教育专员 Stephanie Balme，科技专员 Sophie de Bentzmann 陪同访问。林建华校长在临湖轩西厅会见了代表团，物理学院胡永云副院长陪同会见。会后，代表团与物理学院教师代表亲切座谈，参加座谈的有大气与海洋科学系傅宗玫研究员、张霖研究员、刘永岗研究员和国际量子材料科学中心李源研究员。

In June, a University of Paris-Saclay delegation led by President Prof. Gilles Bloch, accompanied by Director of International Relations Guillaume Garreta, Ms. Stephanie Balme and Ms. Sophie de Bentzmann from the Embassy of France, visited Peking University and met with Faculty of School of Physics. President of Peking University Prof. Jianhua Lin met with the delegation, joint by Associate Dean of School of Physics Yongyun Hu. The delegation discussed with faculty members of School of Physics, including Researchers Zongmei Fu, Lin Zhang and Yonggang Liu from the Department of Atmospheric and Oceanic Sciences and Researcher Yuan Li from the International Center of Quantum Materials.



12 月，巴黎综合理工大学校长 Eric Labaye 访问北京大学，副教务长 Dominique Rossin，副校长 Rachel Maguer，国际及科学媒体关系官员 Sara Tricarico，国际发展办公室副主任 Gaëlle LE GOFF 等陪同访问。郝平校长在临湖轩会见了代表团，教务长龚旗煌院士、物理学院胡永云和朱守华副院长以及其他院系代表陪同会见。会见后，代表团在临湖轩西厅与物理学院、化学学院、信科学院、数学学院代表进行了亲切座谈。

In December, an École Polytechnique Paris delegation led by President Eric Labaye, visited Peking University, accompanied by Vice Provost Dominique Rossin, Officer of International and Media Relations Sara Tricarico, Deputy Director of International Development Gaëlle LE GOFF, etc. President of Peking University, Ping Hao, met with the delegation, accompanied by Provost Academician Qihuang Gong, Vice Deans of School of Physics Profs. Yongyun Hu and Shouhua Zhu as well as representatives from other Schools. After the meeting, the delegation held a discussion with School Representatives.

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

2017 年 7 月 12-14 日，“第七届 ICQs 系列年度学术研讨会”在北京大学物理学院顺利召开，此次会议的主题是“The World of Topological Matters”。会议邀请了包括 2016 年诺贝尔物理学奖获得者、美国普林斯顿大学 Duncan Haldane 教授在内的国内外知名专家学者作精彩报告。

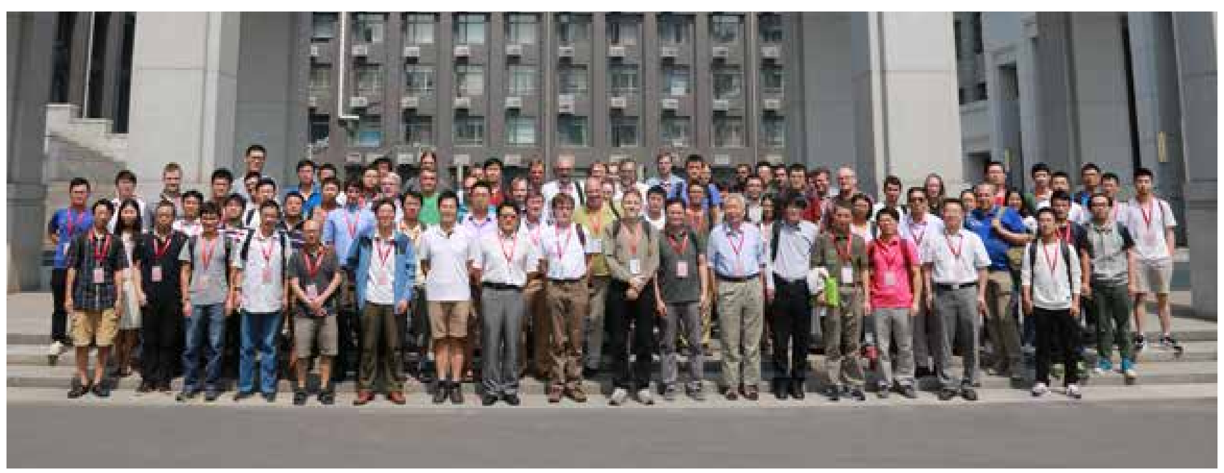
“The 7th ICQs Joint Annual Workshop on The World of Topological Matters” was held during July 12th-14th, 2017. A group of top scientists in the world, including Professor Duncan Haldane (the Noble laureate in 2016), on topological properties of condensed matter and materials were invited to give talks on related topics.

2017 年 8 月 17-19 日，科维理天文与天体物理研究所（KIAA）成功举办“第二届粒子天体物理研讨会”，包括美国、欧洲、日本等国在内的七十余位中外学者与会。

“The Workshop on Astroparticle Physics II” was held by KIAA at Peking University on August 17 to 19, 2017. More than 70 scholars from US, Europe, Jpan and other countries and areas attended this workshop.

“第五届中德强相互作用 QCD 对称性及其物质结构学术研讨会”于 2017 年 8 月 28-31 日成功举办。来自德国、俄国的近四十位国外专家和四十余位国内专家参加会议。

“CRC110 General Meeting of 2017” was held on August 28-31, 2017. The meeting was attended by nearly 40 foreign experts from Germany and Russia and over 40 domestic experts.



“第二届中美放射性核束物理会议”于 2017 年 10 月 15 日 -18 日在北京大学物理学院举办，会议规模约 120 人，其中国外专家 15 人。

“The 2nd China-US-RIB Meeting” was held by School of Physics on October 15-18, 2017. The meeting was attended by 120 attendees including 15 foreign experts.

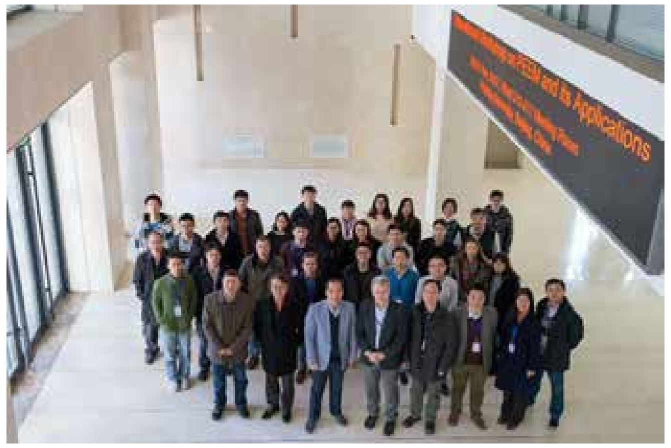
第 12 届重夸克偶素物理国际会议于 2017 年 11 月 6-10 日在北京大学成功举办。国内百余人和来自美国、法国、德国、俄国等国家和地区近八十人参加了本届会议。

“The 12th International Workshop on Heavy Quarkonium” was held by School of Physics Peking University on September 6-10, 2017. The workshop was well attended with about 200 attendees including nearly 80 from US, France, Germany, Russia and other countries and areas.

合作与交流 | *Cooperation*

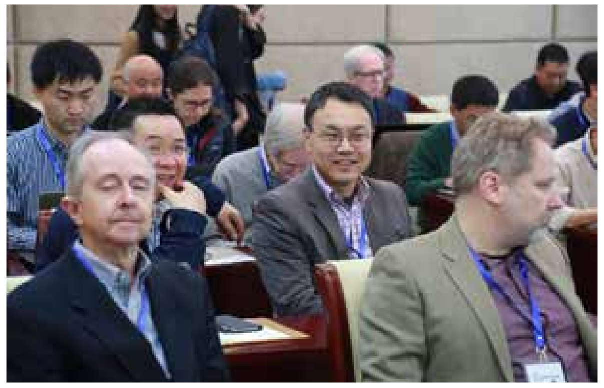
2017 年 11 月 22-23 日，光电子能谱研究及应用国际研讨会在北京大学成功举办。来自中国、德国、英国、日本、香港等国家或地区学术机构的光电子能谱和成像领域的专家、学者们参加了本次研讨会。

“The International Workshop on PEEM and Its Applications” was held by Peking University on September 22-23, 2017. Worldly noted experts from China, Germany, UK, Japan, and Hong Kong area attended this workshop.



“2018 中国 sPHENIX 研讨会”于 2018 年 4 月 22-23 日在北京大学成功举行。会议邀请到美国多位知名学者做精彩报告。

“2018 sPHENIX” was held at Peking University during April 22-23, 2018. Noted scholars from US were invited to give talks on related topics.

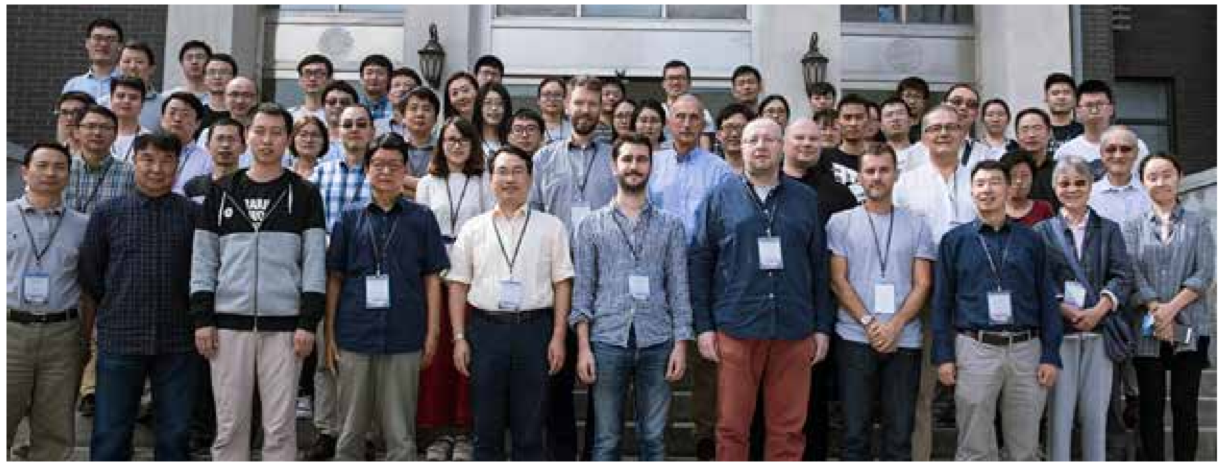


“第 25 届国际稀土永磁与先进磁性材料及其应用大会”于 2018 年 8 月 26-30 日在北京大学成功举行。本次会议共吸引海内外 23 个国家 400 余位专家学者及产业人员参会。

“The 25th International Workshop on Rare-Earth and Future Permanent Magnets and their Applications (REPM 2018)” was held at Peking University on August 26-30, 2018. More than 400 experts and industrial personnel from more than 23 countries and areas attended this workshop.

“低能核动力学与有效核力国际研讨会”于 2018 年 9 月 17-20 日在北京大学物理学院举办。参加会议人数为 70 人，其中外方专家 10 人，国内专家 35 人，研究生人人数为 25 人。

“The PKU-CUSTIPEN workshop on low energy nuclear dynamics and effective nuclear interactions” was held by School of Physics on September 17-20, 2018. The workshop was attended by 70 attendees including 10 foreign experts, 35 domestic experts and 25 graduate students.



“第二届北京大学 - 京都大学拓扑材料科学学术交流会”于 2018 年 9 月 25-28 日在北京大学物理学院举办，会议邀请了包括中国、日本、美国、韩国在内的近四十位国内外知名专家学者作精彩报告。

During September 25-28, 2018, the “2nd Joint PKU-Kyoto-TMS International Workshop” was held at Peking University. Around 40 worldly renowned experts from China, Japan, US, Korea and so on were invited to give talks on related topics.

奖励与荣誉
Awards & Honors

2017 年度：
In 2017,

- 肖云峰、龚旗煌科研团队“非对称微腔光场调控新原理研究”入选 2017 年度“中国高等学校十大科技进展”。
  Yunfeng Xiao and Qihuang Gong’s group won the Ten Major Scientific Progress of Higher Education in China.

- 孙庆丰获国家重点研发计划项目首席。
  Qingfeng Sun was elected as chief of National Key R & D Project.

- 高家红获批基金委重大项目。
  Jiahong Gao was approved by the Natural Science Foundation of China for National Major Projects.

- 江颖、冯济、彭良友、曹庆宏、杨海军获杰出青年基金资助。
  Ying Jiang, Ji Feng, Liangyou Peng, Qinghong Cao and Haijun Yang were awarded the National Funds for Distinguished Young Scientists.

- 朱瑞获优秀青年科学基金资助。
  Rui Zhu was awarded the National Funds for Excellent Young Scientists.

- 孙庆丰、胡小永、王新强入选第三批国家“万人计划”领军人才。林金泰入选万人计划”青年拔尖人才。
  Qingfeng Sun, Xiaoyong Hu and Xinqiang Wang was included into the Science and Technology Innovation Talent of “Ten Thousand Talents Program.” Jintai Lin was included into the Young Topnotch Talents of “Ten Thousand Talents Program.”

- 吴学兵等获 2017 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。
  Xue-Bing Wu was awarded the first-class prize of Natural Science Award of Higher Education Science Research Excellent Achievement (Science and Technology).

- 赵春生等获 2017 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。
  Chunsheng Zhao was awarded the second prize of Natural Science Award of Higher Education Science Research Excellent Achievement (Science and Technology).

- 龚旗煌院士当选为中国光学学会第八届理事会理事长、国际光学委员会副主席。
  Academician Qihuang Gong was elected Chairman of the 8th Council of the Chinese Optical Society and Vice Chairman of the International Optics Commission.

- 刘玉鑫获万人计划教学名师荣誉称号。
  Yuxin Liu won the Outstanding Teacher title of “Ten Thousand Talents Program.”

- 马中水获 2017 年北京市教学名师荣誉称号。
  Zhongshui Ma won the title of Outstanding Teacher of Beijing.

- 彭良友教授荣获中国物理学会饶毓泰物理奖。
  Liangyou Peng won the Rao Yutai Physics Award of the Chinese Physical Society.

- 钱维宏获中国气象学会 " 气象科学技术进步成果奖” 二等奖。
  Weihong Qian won the second prize of Meteorological Scientific and Technological Progress by China Meteorological Society.

2018 年度：
In 2018,

- 沈波团队“氮化物半导体大失配异质外延技术”获 2018 年国家技术发明二等奖。
  Bo Shen’s group won the second prize of National Technology Invention Award.

- 江颖、王恩哥等的研究成果入选“2018 年度中国科学十大进展”
  Ying Jiang and Enge Wang's group won the Top Ten Progress in China.

- 肖云峰获 2018 年度高等学校科学研究优秀成果奖（科学技术）青年科学奖。
  Yunfeng Xiao was awarded the Youth Science Medal of Higher Education Science Research Excellent Achievement (Science and Technology).

- 王楠林课题组获得国家基础科学中心项目。
  Nanlin Wang’s group was approved the National Basic Science Center Project.

- 廖志敏、全海涛、刘雄军、乔宾、肖云峰获得国家杰出青年基金项目资助。
  Zhimin Liao, Haitao Quan, Xiongjun Liu, Bin Qiao and Yunfeng Xiao were awarded the National Funds for Distinguished Young Scientists.

- 孟杰当选欧洲科学院物理与工程学部外籍院士。
  Jie Meng was elected Foreign Member of the European Academy of Sciences.

- 王恩哥获得国际先进材料终身成就奖。
  Enge Wang won the Lifetime Achievement Award in International Advanced Material.

- 江颖荣获 2018 年度陈嘉庚青年科学奖。
  Ying Jiang won the Tan Kah Kee Young Scientist Award.

- 刘永岗荣获“施雅风冰冻圈与环境基金 2018 年度青年科学家奖”。
  Yonggang Liu won the Young Scientist Medal by Shi Yafeng Cryosphere and Environment Fund.

- 王新强、颜学庆通过北京高等学校卓越青年科学家项目评审。
  Xinqiang Wang and Xueqing Yan were approved the Outstanding Young Scientist Project of Beijing Colleges and Universities.

- 龚旗煌、谢心澄当选为发展中国国家科学院院士。
  Qihuang Gong and Xincheng Xie were elected Academicians of the World Academy of Sciences for the advancement of science in developing countries.

- 龚旗煌当选为国际光学工程学会（SPIE）2018 年学会会士。
  Qihuang Gong was elected Fellow of International Society for Optical Engineering (SPIE).

- 刘玉鑫、朱守华等完成的教学研究与实践项目获高等教育国家级教学成果二等奖、北京市教学成果一等奖、北京大学教学成果特等奖。
  Yuxin Liu and Shouhua Zhu won the second prize of national teaching achievement of higher education, the first prize of teaching achievement of Beijing, and the special prize of teaching achievement of Peking University.