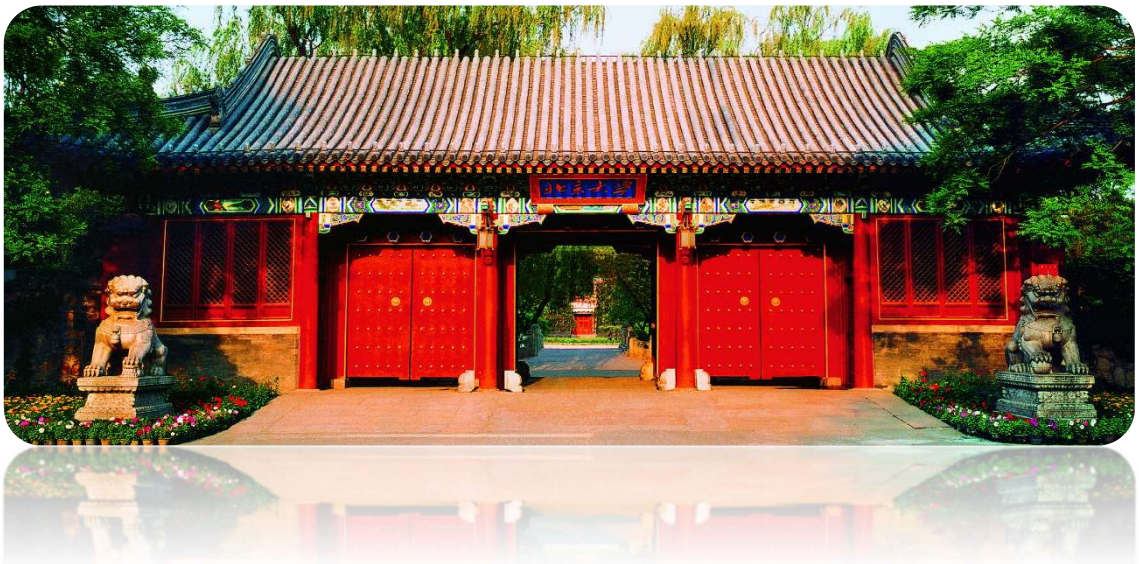
北 京 大 学 科 研 亮 点

(2019 年度)

Peking University
Scientific Research Highlights 2019



目 录

数学科学学院（School of Mathematical Sciences）

1．经典高斯正交系综（GOE）的小间距问题

田刚院士与韦东奕等合作解决了随机矩阵中经典高斯正交系综（GOE）的小间距问题，证明了 GOE 的小间距在极限意义下渐进于泊松分布并得到了小间距的渐进分布函数，是随机矩阵研究领域的重要进展。

The Smallest Gaps Between Eigenvalues of the Gaussian Orthogonal Ensemble

We study the smallest gaps between eigenvalues of the Gaussian orthogonal ensemble (GOE). The main result is that the smallest gaps, after being normalized by n, will converge to a Poisson distribution, and we give the limiting density of the kth normalized smallest gap. It is an important progress in the field of random matrix.

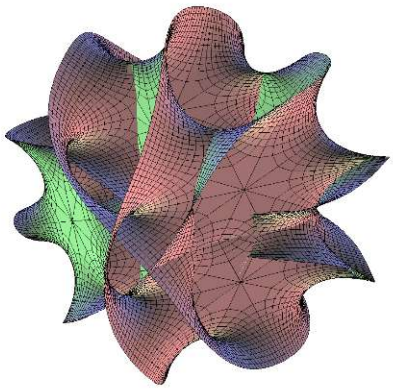
Feng, Renjie; Tian, Gang; Wei, Dongyi, Small gaps of GOE. Geom. Funct. Anal. 29 (2019), no. 6, 1794–1827.

2．全亏格镜像对称和 Gromov-Witten 不变量

整体镜像对称与 Gromov-Witten（GW）不变量的计算是近代数学物理和代数几何方向的热门领域，其核心问题就是如何证明任意亏格的整体镜像对称猜想，并给出一种任意亏格 GW 不变量的有效算法。GW 不变量在超弦理论中被认为是描述世界的基本量，也是现代计数几何的基本不变量。郭帅通过独有的计算技术，与三个团队分别合作证明了五次超曲面这一最典型的紧致 Calabi-Yau 三维流形全亏格镜像对称方面的一系列结构性猜想，彻底解决了该领域 20 多年来一直悬而未解的核心问题之一。

Mirror Symmetry and Gromov-Witten Invariants for All Genera

The computation of the Gromov-Witten (GW) theory of compact Calabi-Yau 3-folds is a central and yet difficult problem in geometry and physics. The key problem is to prove the all genus Mirror Symmetry and give an effective way to compute the all genera GW invariants, which are modern enumerative invariants and are considered as the fundamental invariants for the real world in string theory. Shuai Guo proved a series of structure conjectures for the quantic 3-fold case, which is the simplest compact Calabi-Yau 3-fold, in a series works with three teams. And hence give a complete answer to this central problem which is open for twenty year.

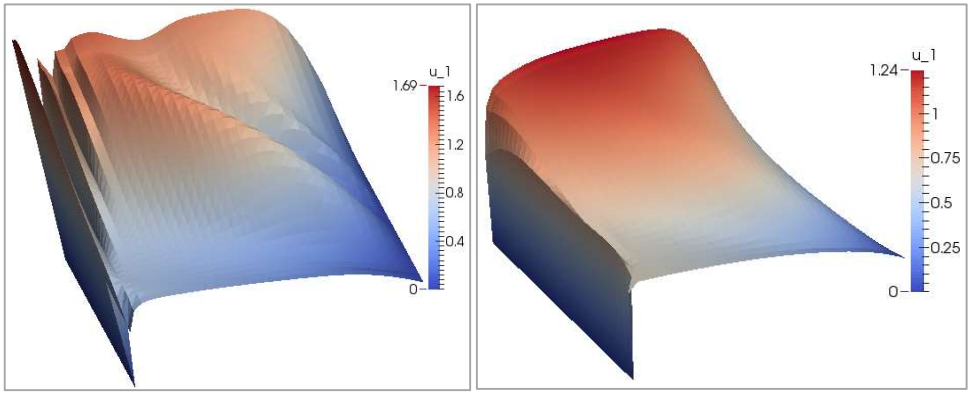


Guo, Shuai; Ross, Dustin ,The genus-one global mirror theorem for the quintic 3-fold. Compos. Math. 155 (2019), no. 5, 995–1024.

Guo, Shuai; Ross, Dustin,Genus-one mirror symmetry in the Landau-Ginzburg model. Algebr. Geom. 6 (2019), no. 3, 260–301.

3. 广义对流扩散方程的稳定化数值方法

基于有限元外微分工具，吴朔男及其合作者给出了广义对流扩散方程的稳定化数值方法。该方法统一适用于各类问题，包括粒子密度、电场、磁场对应的对流扩散方程，在磁约束等离子体核聚变装置等研究课题上具有重要意义。



Numerical solutions before and after the stabilization （稳定化之前和之后的数值解）

Stabilized numerical methods for general convection-diffusion problems

Based on the Finite Element Exterior Calculus, we propose a family of stabilized numerical methods for general convection-diffusion problems. These methods are uniformly applicable to various models, including the convection-diffusion of particle density, electric field, and magnetic field. It has great potential in research topics such as nuclear-fusion devices for magnetic confinement of plasma.

Wu, Shuonan, Xu, Jinchao. Simplex-averaged finite element methods for H(grad), H(curl) and H(div) convection-diffusion problems. SIAM Journal on Numerical Analysis, 58(1), 884-906, 2020.

北京国际数学研究中心（Beijing International Center for Mathematical Research）

1. Fano 簇的 K-半稳定退化的唯一性

许晨阳与合作者证明了 Fano 簇的 K-半稳定退化在 S-等价下的唯一性，这是构造 Fano 簇的 K-模空间的一个基本步骤。K 稳定的概念由北京大学田刚院士于 1996 年引进，之后 K 稳定的概念得到进一步发展并推广到任意极化的 Kähler 流形，成为代数几何重要的概念之一。该论文成果是相关领域研究的重要进展，已发表在世界顶级数学期刊 Annals of Mathematics 上。

Uniqueness of K-polystable degenerations of Fano varieties

To give a general framework for intrinsically constructing moduli spaces of Fano varieties is a challenging question in algebraic geometry, especially if one wants to find a compactification. In this paper, We prove that K-polystable degenerations of Q-Fano varieties are unique. Furthermore, we show that the moduli stack of K-stable Q-Fano varieties is separated. Together with recently proven boundedness and openness statements, the latter result yields a separated Deligne-Mumford stack parametrizing all uniformly K-stable Q-Fano varieties of fixed dimension and volume. The result also implies that the automorphism group of a K-stable Q-Fano variety is finite.

Uniqueness of K-polystable degenerations of Fano varieties, Blum H, Xu C. Annals of Mathematics, 2019, 190(2): 609-656.

2．三维卡拉比-丘环轨形的重塑猜想

重塑猜想利用曲线上的拓扑递归来预测三维卡拉比-丘环轨形上的开-闭 Gromov-Witten 不变量。方博汉与合作者在最广泛的意义上严格证明了这个猜想。重塑猜想位于许多重要的数学物理相关的几何理论的交点，其中 Gromov-Witten 理论是拓扑 A 弦论研究的主要内容之一；作为拓扑 B 弦论的 Eynard-Orantin 拓扑递归理论来自于矩阵模型，是关于曲线的解析理论，它又和可积系统密切关联。这个猜想的证明为之后的许多重要应用打开了大门，比如全亏格的 crepant 消解猜想、Gromov-Witten 理论的模形式性质以及全纯异常方程等。相关论文已在线发表于世界顶尖数学期刊 Journal of the American Mathematical Society（JAMS）上。

On the remodeling conjecture for toric Calabi-Yau 3-orbifolds

The Remodeling Conjecture proposed by Bouchard-Klemm-Mariño-Pasquetti (BKMP) relates the A-model open and closed topological string amplitudes (the all genus open and closed Gromov-Witten invariants) of a semiprojective toric Calabi-Yau 3-manifold/3-orbifold to the Eynard-Orantin invariants of its mirror curve. It is an all genus open-closed mirror symmetry for toric Calabi-Yau 3-manifolds/3-orbifolds. In this paper, we present a proof of the BKMP Remodeling Conjecture for all genus open-closed orbifold Gromov-Witten invariants of an arbitrary semiprojective toric Calabi-Yau 3-orbifold relative to an outer framed Aganagic-Vafa Lagrangian brane. We also prove the conjecture in the closed string sector at all genera.

On the remodeling conjecture for toric Calabi-Yau 3-orbifolds, Fang B, Liu C C, Zong Z, Journal of the American Mathematical Society, 2020, 33(1): 135-222

3．曲面自同构的庶几同调谱半径

在低维拓扑领域，曲面的自同胚映射是活跃的研究课题。映射在同调群上表现为线性变换，变换的特征值有助于探测映射的拓扑复杂性，这一途径在曲面的有限叶复叠空间上引申出更丰富的运用。2013 年，菲尔兹奖获得者 C. T. McMullen 对于曲面上的伪 Anosov 自同构证明了重要的间隙定理。他还猜测：给定任何的曲面自同

胚，如果它的映射类拓扑熵大于零，那么它将在曲面的某个复叠上表现出一个同调特征值，是位于单位圆周之外。通过运用双曲三维流形和有限复叠的新生工具，结合经典的 Nielsen 不动点理论，刘毅完整证明了上述猜想，相关论文已在线发表于世界顶尖数学期刊 Journal of the American Mathematical Society（JAMS）上。

Virtual homological spectral radii for automorphisms of surfaces

In low-dimensional topology, a surface automorphism refers to any orientation-preserving self-homeomorphism of a compact orientable surface, and a virtual property refers to a property that holds up to lifting to some finite covering space. It has been conjectured by C. T. McMullen that any surface automorphism of positive mapping-class entropy possesses a virtual homological eigenvalue which lies outside the unit circle of the complex plane. In this paper, it is shown that any surface automorphism of positive mappingclass entropy possesses a virtual homological eigenvalue which lies outside the unit circle of the complex plane.

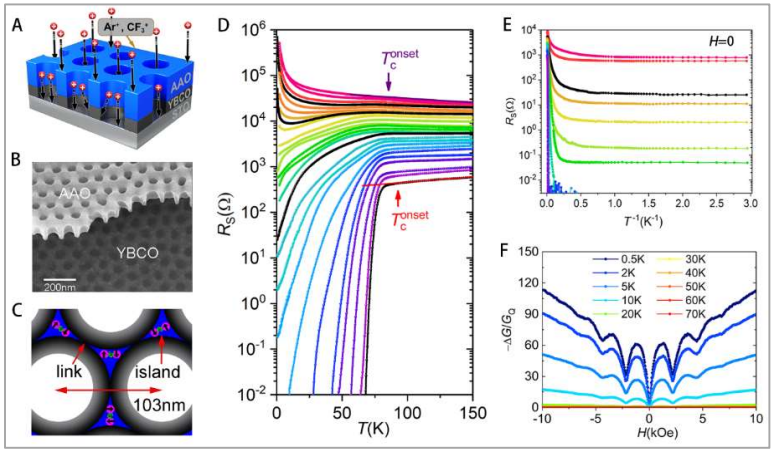
Virtual homological spectral radii for automorphisms of surfaces, Yi Liu, Journal of the American Mathematical Society (2019 Early View) (DOI: https://doi.org/10.1090/jams/949)

物理学院（School of Physics）

1．在高温超导薄膜中证实二维反常金属态

二维反常金属态是否存在近三十年来一直悬而未决的重要物理问题。王健研究组与合作者在高温超导纳米多孔钇钡铜氧薄膜中首次证实了以库珀对为载流子的二维反常金属态。该工作结束了对于二维反常金属态的学术争议，为研究反常金属态的量子起源提供了新的思路。

The demonstration of two-dimensional anomalous metallic state in high-temperature superconducting films



Whether a two-dimensional anomalous metallic state can exist remains an unresolved physical question over the past 30 years. For the first time, Jian WANG team and collaborators demonstrate the existence of anomalous metallic state, of which the carriers are Cooper pairs, in high-temperature

superconducting YBCO films patterned with an array of holes. This work finishes the academic controversy on the anomalous metallic state and paves the way for investigating its quantum origin.

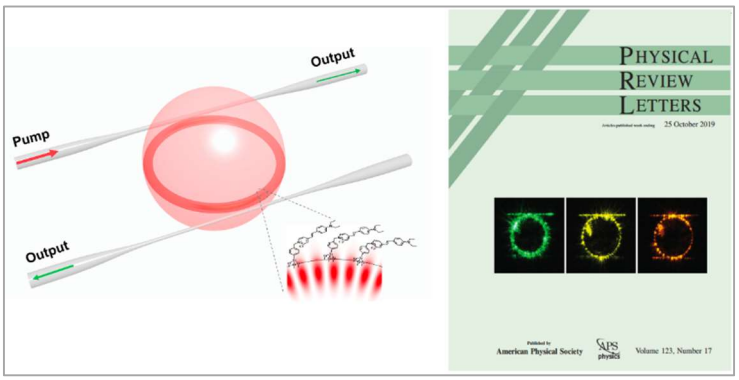
Intermediate bosonic metallic state in the superconductor-insulator transition. C. Yang, Y. Liu, Y. Wang, L. Feng, Q. He, J. Sun, Y. Tang, C. Wu, J. Xiong, W. Zhang, X. Lin, H. Yao, H. Liu, G. Fernandes, J. Xu, J. M. Valles Jr., J. Wang, Y. Li. Science 366, 1505-1509 (2019).

2. 微腔增强非线性转化效率

光学微腔可以在时空维度上束缚光场，是研究微纳尺度下光与物质相互作用的重要体系。肖云峰/龚旗煌团队首次实现有机分子修饰的二氧化硅微腔的高效三次谐波产生，比此前报道的二氧化硅微腔转换效率提高了四个量级，接近晶体微环腔三次谐波的最高转换效率，被 Physical Review Letters 以封面及编辑推荐形式亮点报道。

Surface modified microcavity boosts nonlinear optics

Silica whispering-gallery microcavities are mainstay photonic devices for their intrinsically ultralow loss in the broadband spectra and the mature fabrication in modern technology, but unfortunately suffer from low second- and third-order optical nonlinearity. PKU researchers Xiao Yun-Feng and Gong Qihuang et al. have successfully developed the surface functionalization method to bridge microcavities with the vast library of nonlinear molecules, realizing the gigantically enhanced third-order nonlinear optics. Experimentally, they observed that the conversion efficiency of third harmonic generation in a functionalized microcavity reached ~1,680%/W^2, which was approximately four orders of magnitude higher than that in a best reported silica microcavity.



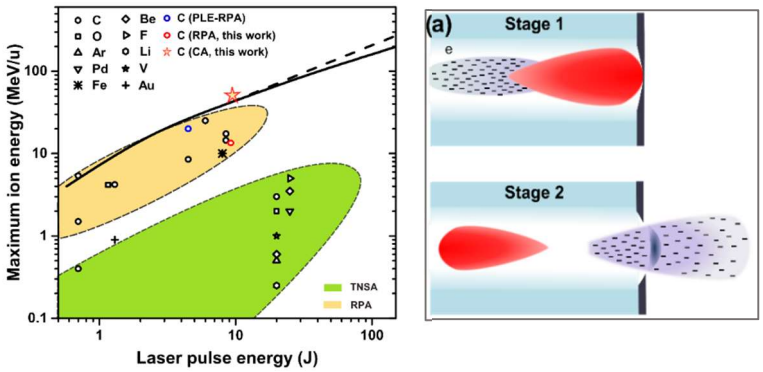
Microcavity nonlinear optics with an organically functionalized surface, J.-h. Chen, X. Shen, S.-J Tang, Q.-T. Cao, Q. Gong, Y.-F Xiao, Physical Review Letters 123 173902 (2019)

3.纳米靶创造激光离子加速新纪录

高能离子在肿瘤治疗与核物理研究中有着广泛的用途。用高功率激光加速离子是正在被广泛研究的最新的离子加速方法。马文君/颜学庆团队近期通过采用先进的纳米靶材，利用一种新的级联加速机制，将飞秒脉冲加速重离子的最高能量纪录提高了 1.6 倍，获得了 580 兆电子伏的碳离子。

Record-breaking laser-accelerated ions from nanotargets

Highly energetic heavy ions are very useful for tumor therapy and nuclear physics research. Laser acceleration of ions are being widely studied as a cutting-edge acceleration technique. Prof. W.J. Ma and Prof. X.Q. Yan's teams recently rise the energy record of laser-accelerated heavy ions by a factor of 2, up to 580 MeV for carbon ions, by employing a new cascaded acceleration scheme with advanced nanotargets.



Laser Acceleration of Highly Energetic Carbon Ions Using a Double-Layer Target Composed of Slightly Underdense Plasma and Ultrathin Foil, W. J. Ma, I. J. Kim, J. Q. Yu, I. W. Choi, P. K. Singh, H. W. Lee, J. H. Sung, S. K. Lee, C. Lin, Q. Liao, J. G. Zhu, H. Y. Lu, B. Liu, H. Y. Wang, R. F. Xu, X. T. He, J. E. Chen, M. Zepf, J. Schreiber, X. Q. Yan and C. H. Nam. Physical Review Letters 122，014803 （2019）

科维理天文与天体物理研究所 (Kavli Institute for Astronomy and Astrophysics)

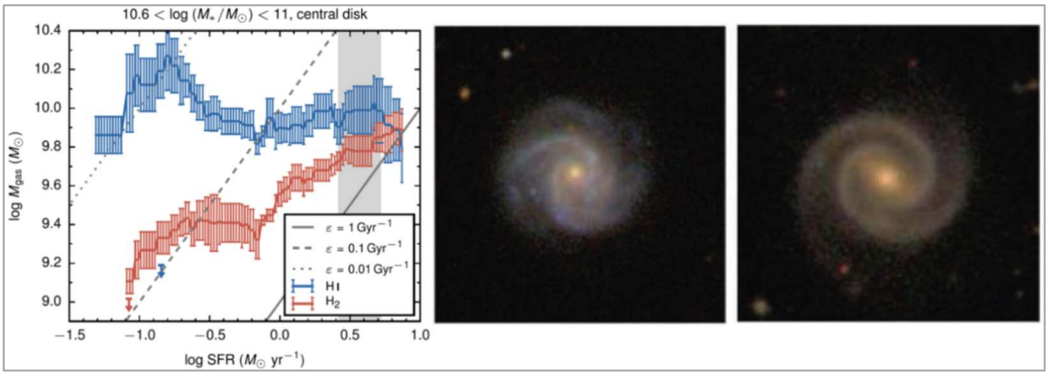
1．死亡的大质量盘星系中含有惊人的大量中性氢冷气体

近邻宇宙中死亡的大质量星系被广泛认为只含有少量的冷气体。彭影杰团队通过对从光学到射电的巡天数据的系统研究，首次发现死亡的大质量盘星系往往含有惊人的大量的中性氢冷气体，其死亡的原因是由于所含的分子氢耗尽和恒星形成效率降低共同导致。这在星系领域首次清楚的展示了大质量盘星系死亡的过程和机制。

Massive Quiescent Disk Galaxies Have a Surprisingly Large Atomic Gas Reservoir

Local massive quiescent galaxies are commonly believed to be gas poor. A team led by Yingjie PENG finds for the first time that, on the contrary, massive quiescent disk galaxies in the nearby universe often have a remarkably large amount of cold atomic hydrogen gas. Massive quiescent disk galaxies are quenched because of their significantly reduced molecular gas content, lower dust content, and lower star formation efficiency. These new findings clearly demonstrate the detailed star formation quenching process in massive disk

galaxies for the first time.

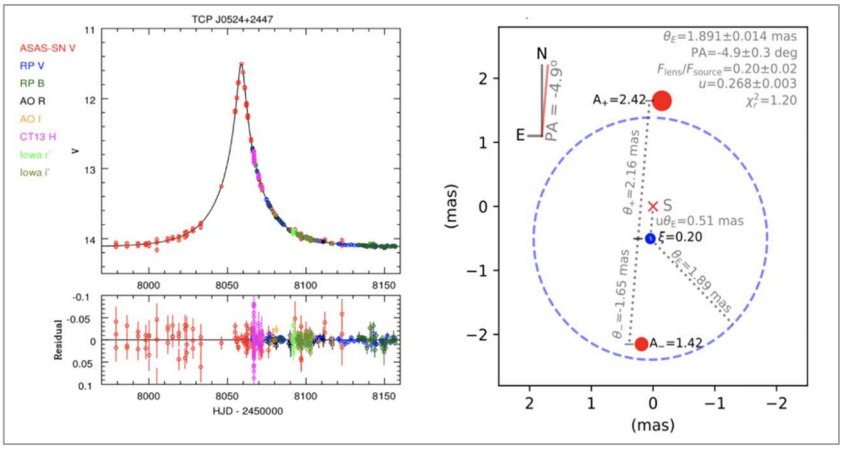


Nearly all Massive Quiescent Disk Galaxies Have a Surprisingly Large Atomic Gas Reservoir, C. Zhang, Y. Peng, L.C. Ho, R. Maiolino, A. Dekel, Q. Guo, F. Mannucci, D. Li, F. Yuan, A. Renzini, J. Dou, K. Guo, Z. Man, Q. Li, The Astrophysical Journal Letters, 884, 52 (2019)

2. 首次实现分辨微引力透镜双像

一个世纪前，爱因斯坦预言了微引力透镜现象，即背景恒星的光在经过观测者视线方向的一个（透镜）天体时，会受其引力作用偏折成两个像。东苏勃研究员团队利用光干涉阵 VLTI-GRAVITY，首次成功分辨了微引力透镜双像，为测量透镜的质量开辟了一个新途径，可用于未来搜寻尚未被发现的孤立的恒星级黑洞。

First Resolution of Microlensed Images



Using an optical interferometer VLTI-GRAVITY, Prof. Subo DONG and his team have resolved the two images of a microlensed source star for the first time, more than a century after Einstein first predicted that such image splitting could be caused by the gravity of another (lens) object along the sightline to the source. Their detection offers a key missing ingredient that enables measuring the lens mass, and it opens the path to identify heretofore undetected isolated black holes lurking in the Galaxy.

First Resolution of Microlensed Images, Dong, Subo; Mérand, A.; Delplancke-Ströbele, F.; Gould, Andrew; Chen, Ping et al., The Astrophysical Journal, 871, 70 (2019)

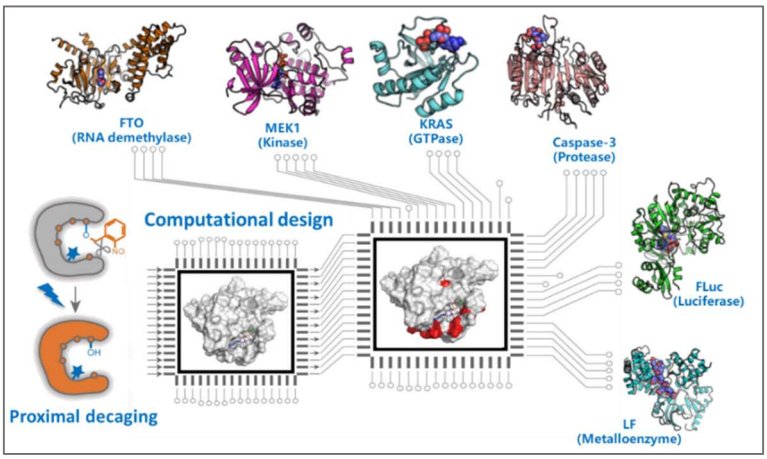
化学与分子工程学院（College of Chemistry and Molecular Engineering)

1．在活体内为蛋白质装上“开关”

蛋白质的在体调控对研究动态生物学过程至关重要。陈鹏教授与王初教授团队合作开发了一种可以在活体环境下，瞬时激活任意目标蛋白质的化学生物学新技术（CAGE-prox）。利用该技术，他们实现了细胞内激酶信号通路的正交激活，完成了细胞凋亡蛋白酶的瞬时激活和酶切底物的组学鉴定，并通过激活金属蛋白酶致死因子开发了基于抗肿瘤蛋白质前药的治疗策略。该方法为今后深入开展蛋白质动态修饰和化学干预研究提供了有力的工具，在基础生物学研究和蛋白质药物研发等一系列领域都具有广阔的应用前景。

Time-resolved protein activation in living systems

Precise perturbation of protein function is crucial to dissect various dynamic biological processes. Prof. Peng CHEN and Chu WANG have collaborated to develop a time-resolved protein activation strategy based on bioorthogonal decaging and computational design with the remarkable simplicity and generality in living system.



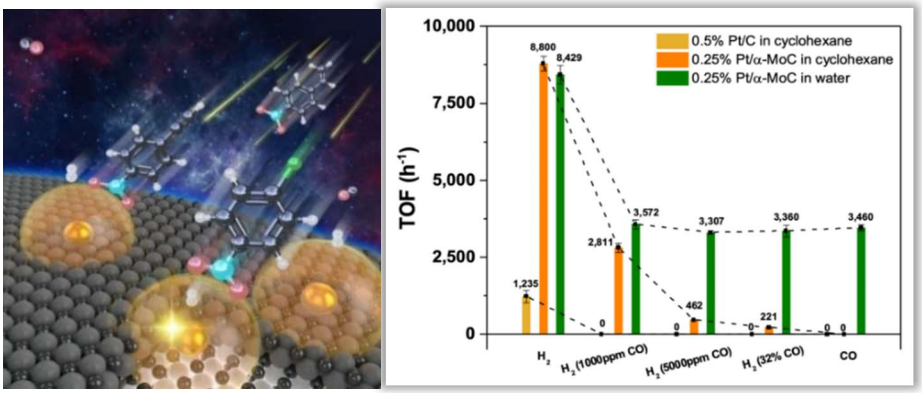
Wang J, Liu Y, Liu YJ, Zheng S, Wang X, Zhao J, Yang F, Zhang G, Wang C, Chen P*. Time-resolved protein activation by a universal proximal decaging strategy in living systems. Nature, 2019, 569, 509-13.*

2．原子级分散 Pt/α-MoC 实现抗 CO 毒化高效选择性加氢

催化加氢过程是现代工业的重要过程，是清洁燃料和高阶化学品生产中的关键步骤。在催化加氢工业过程中，虽然使用粗氢作为氢源具有工业装置简单、更高的经济性等特点，但是粗氢中含有的少量一氧化碳(从几百到几千 ppm)会造成加氢催化剂很快失活。马丁团队通过对 Pt/α-MoC 催化剂的电子性质的精确调控，即通过定向控制碳化钼基底和负载于其上的原子级分散的 Pt 物种间的电子转移实现了抗 CO 加氢， 开辟了利用粗氢、重整气乃至 CO+H2O 等多种氢源直接用于高效选择性加氢反应的新途径。

CO-tolerant Pt catalyst for catalytic hydrogenation

Trace amount of CO in the feed will kill the activity for noble metal-catalzyed hydrogenation reaction. By altering the electronic structure of Pt by the substrate, Prof. Ding MA and his team designed an atomically-dispersed Pt_1/α-MoC which is highly active CO-resistant catalyst for the selective hydrogenation even under high concentration of CO. This opens a new route for the design of CO-tolerant hydrogenation catalyst towards industrial application.



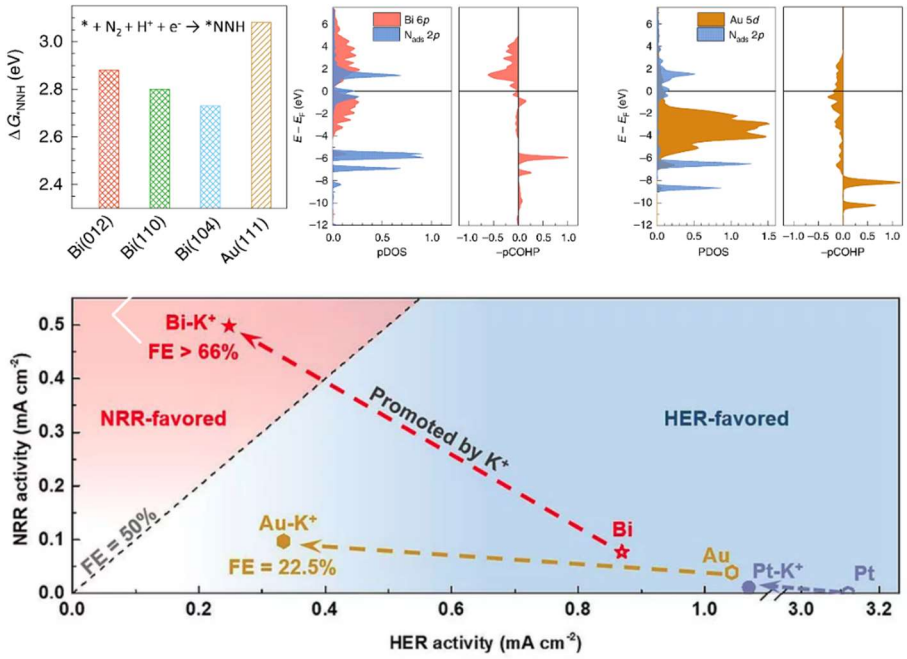
A highly CO-tolerant atomically dispersed Pt catalyst for chemoselective hydrogenation, L. Lin, S. Yao, R. Gao, X. Liang, Q. Yu, Y. Deng, J. Liu, M. Peng, Z. Jiang, S. Li, YW. Li, XD. Li, W. Zhou, D. Ma, Nature Nanotechnology 14, 354 (2019)

3. 用于氮气电还原反应的高活性铋基纳米催化剂

氮气电还原反应可以实现温和条件下的可持续合成氨。张亚文/严纯华研究组和合作者发现，在常温常压下，铋基纳米晶在含钾的电解质水溶液中可达到 66%的法拉第效率和 200 mmol g^{-1} h-1 的产氨速率，其本征活性来源于主族元素铋的 6p 能带和氮 2p 轨道的强烈相互作用。

Nitrogen Electroreduction Reaction

Sustainable ammonia production can be realized via electrochemical nitrogen reduction reaction (NRR) over the catalysts with both high activity and selectivity. Yawen ZHANG and Chunhua YAN team and collaborators demonstrated that the bismuth nanocrystals with potassium ions in water generated the Faradaic efficiency of 66% and ammonia yield of 200mmol g^{-1} h^{-1} under ambient conditions. The intrinsic high activity of bismuth element stemmed from the strong interaction between bismuth 6p bands and nitrogen 2p orbitals.

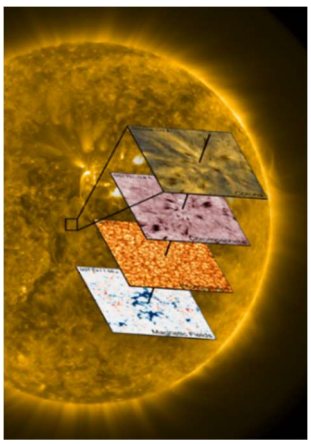


Promoting nitrogen electroreduction to ammonia with bismuth nanocrystals and potassium cations in water, Y.-C. Hao1, Y. Guo1, L.-W. Chen, M. Shu, X.-Y. Wang, T.-A. Bu, W.-Y. Gao, N. Zhang, X. Su, X. Feng, J.-W. Zhou, B. Wang, C.-W. Hu, A.-X. Yin, R. Si*, Y.-W. Zhang*, C.-H. Yan*, Nature Catalysis 2 448 (2019)*

地球与空间科学学院（School of Earth and Space Sciences）

1．发现太阳针状物的产生机制及其对日冕的加热效应

田晖教授和 Tanmoy Samanta 等通过望远镜观测揭示了磁重联产生太阳针状物的机制，并发现针状物在传播过程中被加热到百万度的量级。这一研究将日冕加热与太阳低层大气中的磁活动直接联系起来，从而重新梳理了日冕加热的研究思路。



图：古迪太阳望远镜(GST)和太阳动力学天文台卫星(SDO)对太阳大气不同层次的协同观测结果。层叠图从下到上分别是光球纵向磁场、光球辐射、色球辐射和日冕辐射图。

Generation of Solar Spicules and Subsequent Atmospheric Heating

Through telescope observations, Prof. Hui Tian and Dr. Tanmoy Samanta found that magnetic reconnection drives solar spicules. They also found that spicules are subsequently heated to about one million Kelvin during their propagation. Their research reveals a direct link between magnetic activities in the lower solar atmosphere and coronal heating, which has significantly improved our understanding of coronal heating.

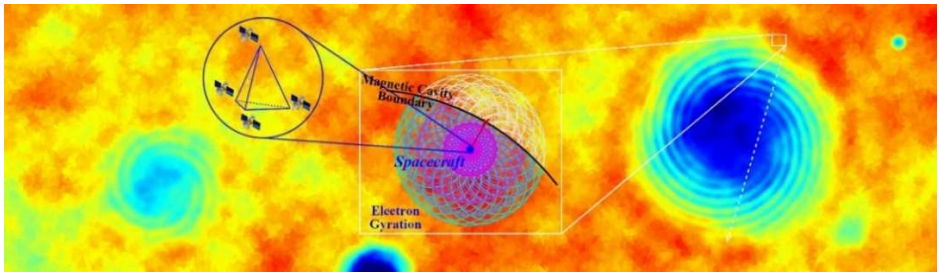
Generation of Solar Spicules and Subsequent Atmospheric Heating, T. Samanta, H. Tian, V. Yurchyshyn, H. Peter, W. Cao, A. Sterling, R. Erdélyi, K. Ahn, S. Feng, D. Utz, D. Banerjee, Y. Chen, Science, 366, 890 (2019)

2. 太空电子尺度磁洞的几何形态与形成机制

电子尺度磁洞是一种尺度极小的电子漩涡，广泛存在于湍动等离子体环境中。宗秋刚教授带领的研究小组利用一种创新的能量粒子遥测方法，揭示了电子尺度磁洞的几何形态和机制，为理解湍动能量在电子尺度的耗散做出贡献。

Electron scale magnetic cavities in turbulent plasmas

Electron scale magnetic cavities are extremely small coherent structures formed in magnetized turbulent plasmas. By applying an innovative particle sounding technique, Prof. Qiugang ZONG and his team directly depict the boundary of an electron scale magnetic cavity and uncover its circular geometry, which contributes to the understanding of the structure.



MMS observations of electron scale magnetic cavity embedded in proton scale magnetic cavity, H. Liu, Q.-G. Zong, H. Zhang, C. J. Xiao, Q. Q. Shi, S. T. Yao, J. S. He, X.-Z. Zhou, C. Pollock, W. J. Sun, G. Le, J. L. Burch, R. Rankin, Nature Communications 10 1040 (2019)

生命科学学院（School of Life Sciences）

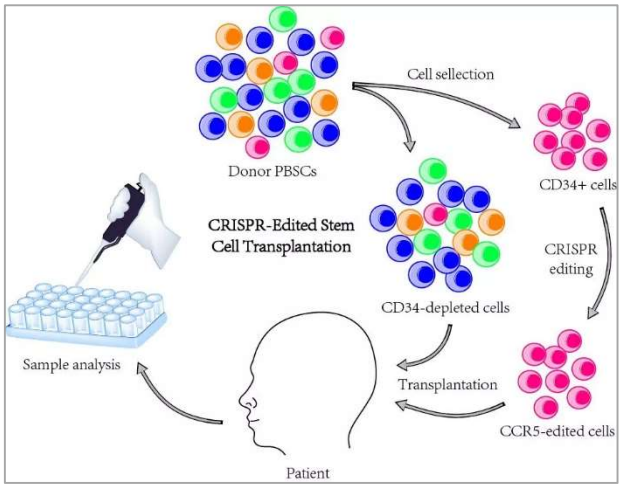
1. CRISPR-Cas9 基因编辑技术的临床应用

CRISPR 基因编辑技术被广泛用于编辑细胞的基因组，表现出巨大的临床应用潜力。邓宏魁教授团队建立了基于 CRISPR 在人成体造血干细胞上进行基因编辑的技术体系，实现了经基因编辑后的造血干细胞在人体内长期稳定的造血系统重建，证明了基因编辑应用在临床上的可行性和安全性。

CRISPR-Edited Stem Cells in a Clinical Trial

CRISPR-Cas9 technology has been widely applied in gene editing and is promising for gene therapy. Prof. Hongkui DENG and his team successfully transplanted CRISPR-edited CCR5-ablated hematopoietic stem and progenitor cells (HSPCs) into a patient with HIV-1 infection and acute lymphoblastic leukemia, and explored the feasibility and safety of this gene-editing approach.

The acute lymphoblastic leukemia was in complete remission with full donor chimerism, and donor cells carrying the ablated CCR5 persisted for more than 19 months without gene editing–related adverse events. These results show the proof of principle that transplantation and long-term engraftment of CRISPR-edited allogeneic HSPCs can be achieved.



CRISPR-Edited Stem Cells in a Patient with HIV and Acute Lymphocytic Leukemia. L. Xu, J. Wang, Y. Liu, et al. N Engl J Med 2019; 381:1240-1247 (2019)

2. 揭示了“植物同种花粉优先”现象的一种分子调控机制

瞿礼嘉教授团队首次在模式植物拟南芥中证明七个花粉管吸引信号 AtLURE1 及其受体 PRK6 调控“植物同种花粉优先”现象，鉴定了新类型花粉管吸引信号“绣球”，建立了育性调控的新模型，为作物远缘杂交育种提供了新的理论依据。

Molecular mechanism controlling Conspecific Pollen Precedence Revealed

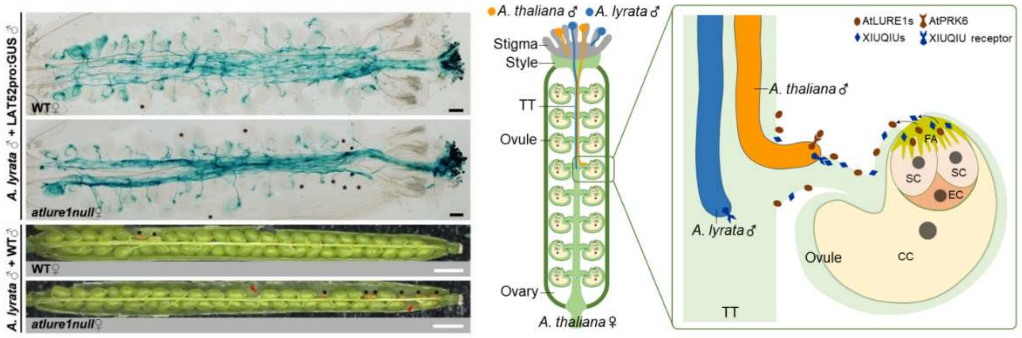


Figure 1 Pollen tube competition assays revealed that AtLURE1s promoted conspecific pollen precedence for fertilization.

Figure 2 Working model of AtLURE1/PRK6-mediated conspecific pollen precedence in Arabidopsis thaliana.

Professor Li-Jia QU and his research team from School of Life Sciences discovered the seven pollen tube attractants, AtLURE1 peptides, and their receptor PRK6, as the signal molecules and receptor, respectively that are

involved in the control of conspecific pollen precedence, a famous phenomenon observed over 160 ago. Meanwhile, they identified a new type of pollen tube attractants XIUQIU peptides, and established a new working model of pollen tube guidance-mediated control of plant fertility, which would provide a new theoretical base for the work to overcome the distant interspecific barriers in order to facilitate crop breeding through hybridization.

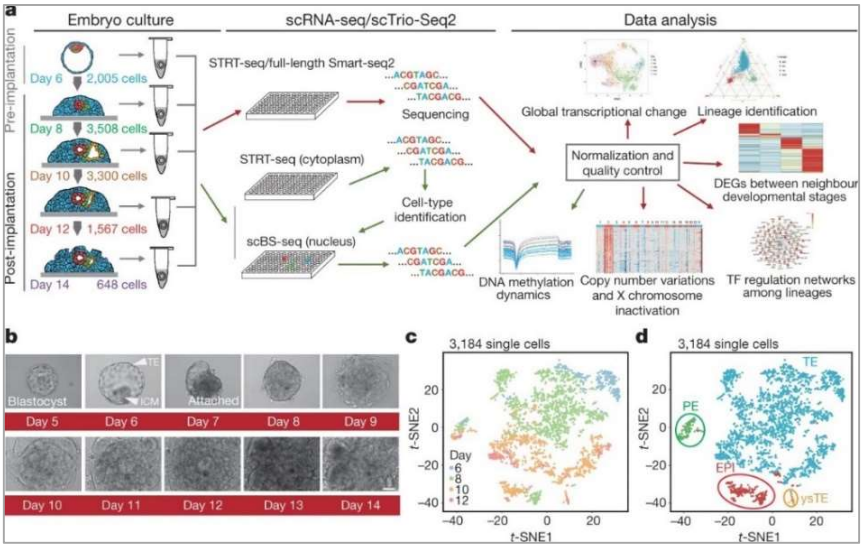
Cysteine-rich peptides promote interspecific genetic isolation in Arabidopsis, Zhong S., Liu M., Wang Z., Huang Q., Hou S., Xu Y.-C., Ge Z., Song Z., Huang J., Qiu X., Shi Y., Xiao J., Liu P., Guo Y.-L., Dong J., Dresselhaus T., Gu H., Qu L.-J., Science 364: eaau9564 (2019).

3. 利用单细胞转录组和 DNA 甲基化组图谱重构人类胚胎着床过程

汤富酬团队结合体外模拟人类着床策略和高精度单细胞多组学测序技术，首次重构了人类胚胎着床过程，系统解析了这一关键发育过程中 X 染色体随机失活、细胞谱系特异性基因组重新甲基化等生物学事件的分子机制。

Reconstituting the transcriptome and DNA methylome landscapes of human implantation

By combining an in vitro culture system for the development human embryos after implantation and single-cell multi-omics sequencing technologies, individual cells from human peri-implantation embryos were systematically analyzed. Female embryos showed initiation of random X chromosome inactivation based on analysis of parental allele-specific expression of X-chromosome-linked genes during implantation. Prof. Fuchou TANG and his team provide insights into the complex molecular mechanisms that regulate the implantation of human embryos, and helps to advance future efforts to understanding early embryonic development and reproductive medicine.



Reconstituting the transcriptome and DNA methylome landscapes of human implantation, Zhou, F; Wang, R; Yuan, P; Ren, YX; Mao, YU; Li, R; Lian, Y; Li, JS; Wen, L; Yan, LY; Qiao, J; Tang, FC, Nature 572（7771） (2019)

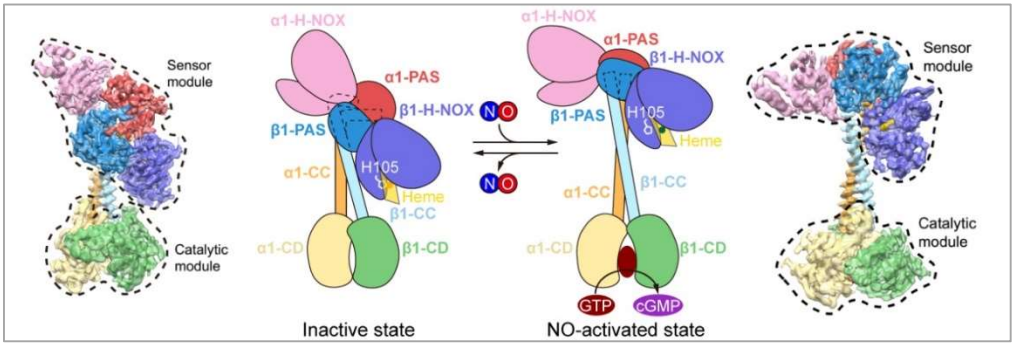
分子医学研究所 (Institute of Molecular Medicine)

1. 冷冻电镜显示了一氧化氮受体——人源可溶性鸟苷酸环化酶的激活机制

可溶性鸟苷酸环化酶是一氧化氮受体。它在很多生理和病理过程中扮演重要角色。陈雷研究组解析了人源鸟苷酸环化酶在多种功能状态下的冷冻电镜结构，揭示了一氧化氮的激活机制。

Activation mechanism of nitric oxide receptor, human soluble guanylate cyclase, is revealed by cryo-EM

Soluble guanylate cyclase is the primary nitric oxide (NO) sensor in human. It plays a central role in NO signaling and is implicated in many essential physiological processes and disease conditions. Group lead by Lei CHEN in Institute of Molecular Medicine have solved the cryo-EM structures of the human sGC in different functional states, which revealed the activation mechanism of sGC by NO molecule.



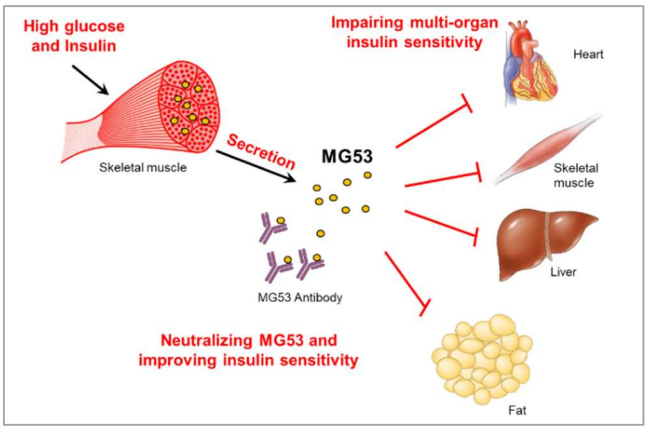
Structural insights into the mechanism of human soluble guanylate cyclase, Y. Kang, R. Liu, J. X. Wu, L. Chen, Nature 574, 206-210(2019).

2. 葡萄糖敏感型肌肉因子/心肌因子 MG53 调节全身胰岛素反应和代谢稳态

肖瑞平教授团队研究发现高糖、高胰岛素引起 MG53 分泌，血液中 MG53 会抑制全身各组织胰岛素信号敏感性，而且用特异性抗体中和 MG53 能提高全身胰岛素敏感性、降低血糖。这为代谢综合征和 2 型糖尿病提供了免疫治疗新思路。

Glucose-Sensitive Myokine/Cardiokine MG53 Regulates Systemic Insulin Response and Metabolic Homeostasis

Professor Rui-ping XIAO and her colleagues find that high glucose or high insulin could induce MG53 secretion from striated muscle. The circulating MG53 inhibits the insulin signal sensitivity of skeletal muscle, liver, heart, fat and other tissues. Neutralizing circulating MG53 with monoclonal antibodies improves the insulin sensitivity of whole body and reduces blood glucose. These results provides a new idea of immunotherapy for metabolic syndrome and type 2 diabetes.



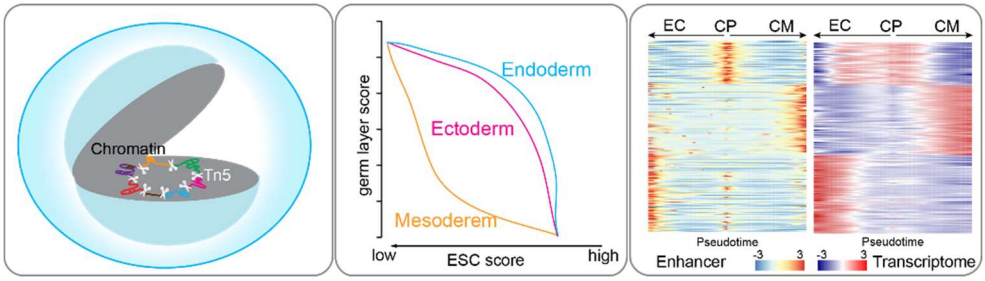
Glucose-Sensitive Myokine/Cardiokine MG53 Regulates Systemic Insulin Response and Metabolic Homeostasis, H. K. Wu, Y. Zhang, C. M. Cao, X. Hu, M. Fang, Y. Yao, L. Jin, G. Chen, P. Jiang, S. Zhang, R. Song, W. Peng, F. Liu, J. Guo, L. Tang, Y. He, D. Shan, J. Huang, Z. Zhou, D. W. Wang, F. Lv, R. P.Xiao, Circulation 139:901-914(2019).

3. 开发单细胞 itChIP-seq 解码发育中细胞命运决定

何爱彬研究组首次开发了高灵敏度单细胞 sc-itChIP-seq 技术，整合已有单细胞转录组技术，解码细胞命运决定的表观遗传调控机制。该技术帮助我们解码了胚胎干细胞退出全能性分化为三胚层谱系的表观遗传轨迹，揭示了胚胎心脏干细胞命运决定过程转录组与表观组调控的异步性机制。

Developing single-cell itChIP-seq for deciphering cell fate decision during development

For the first time, Aibin HE's group developed a high-sensitivity single-cell itChIP-seq, integrated with existing single-cell RNA-seq technology, to decipher the epigenetic mechanisms controlling cell fate decision. Single-cell itChIP-seq revealed the epigenetic trajectories for priming three germ layers and the regulatory distinction between transcriptome and epigenome during cardiac progenitor cell differentiation towards downstream lineages.



Profiling chromatin states using single-cell itchip-seq, S. Ai, H. Xiong, C.C. Li, Y. Luo, Q. Shi, Y. Liu, X. Yu, C. Li, A. He, Nature Cell Biology 21:1164-1172 (2019).

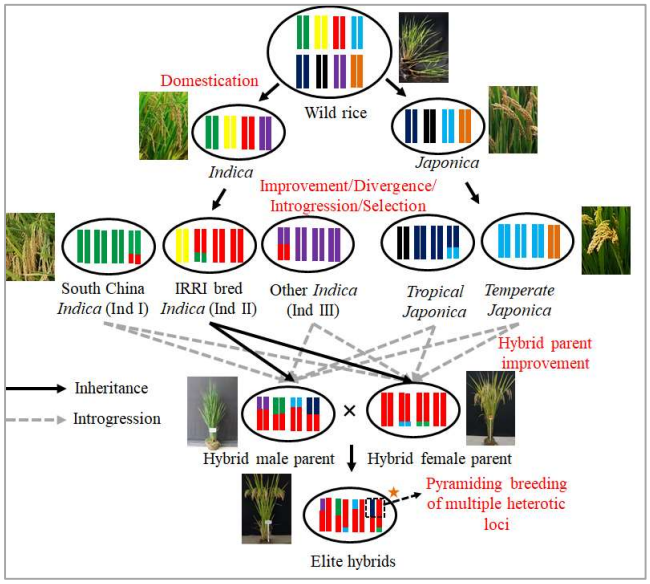
现代农学院（School of Advanced Agricultural Sciences）

1. 水稻育种过程中杂种优势形成的遗传机制

邓兴旺团队通过对 2000 多份水稻杂交 F1 材料的重测序，鉴定了 143 个杂种优势位点。溯源分析显示这些位点在野生稻中已存在，在水稻驯化过程中受到分化选择。在杂交育种过程中，育种家将不同水稻亚种中的位点导入到杂交亲本中，聚合正效应位点形成水稻中的杂种优势。

Genetic basis of heterosis formation during rice breeding

By resequencing more than 2000 rice F1 hybrids, Prof. Xingwang DENG and his team identified 143 heterotic loci. These loci existed in wild rice, and were divergently selected among rice subpopulations, including indica, aus, and japonica. During modern rice hybrid breeding, heterotic loci were introgressed into varieties by fixing loci with positive effect and pyramid breeding.



Divergent selection and genetic introgression shape the genome landscape of heterosis in hybrid rice, Z. Lin, P. Qin, X. Zhang, C. Fu, H. Deng, X. Fu, Z. Huang, S. Jiang, C. Li, X. Tang, X. Wang, G. He, Y. Yang, H. He, X.W. Deng, Proc Natl Acad Sci U S A 9 4623 (2020)

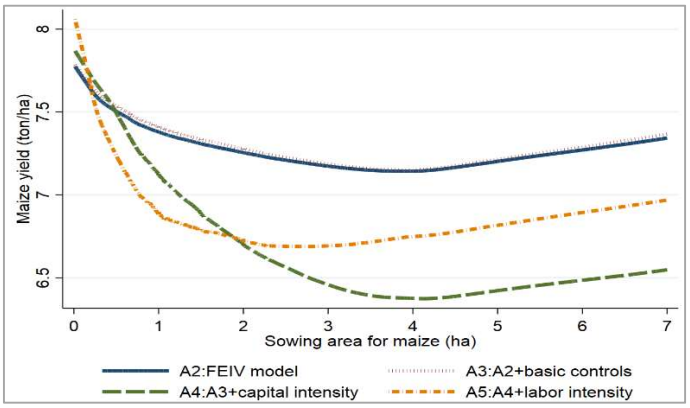
2. 农户规模与生产力关系

在许多亚洲和非洲发展中国家，农户规模与生产力（单产）之间存在的负向关系一直是发展经济文献中的一个悖论。黄季焜团队研究表明：当农户扩大经营规模时面临的预算约束阻止其采用资本密集型生产技术，这为该悖论提供了新的解释。

New explanation on the paradox of inverse farm-productivity relationship

The inverse farm size-productivity relationship in developing countries is a paradox in economic development literature. In addition to land market distortions, Prof. Jikun HUANG and his team show that the budget constraint

prevents larger farms from taking the capital-intensive technology and this offers an alternative explanation for the paradox.



Impact of technology choice on the farm size-productivity relationship

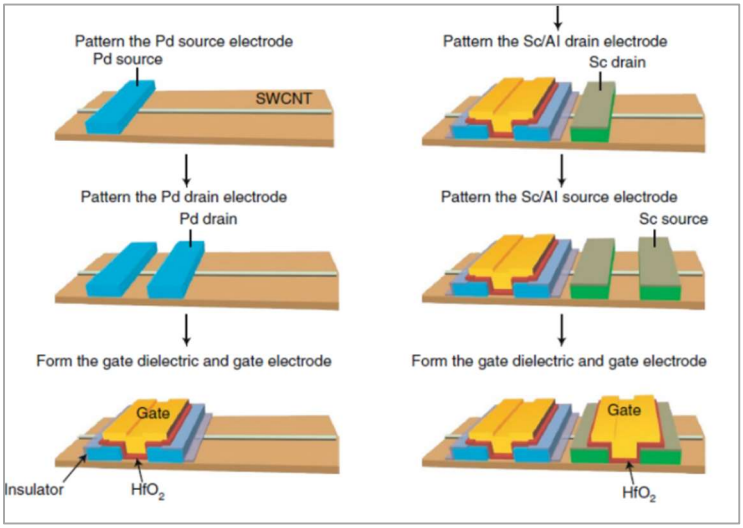
Y. Sheng, J. Ding and J. Huang (*), 2019, "The Relationship between Farm Size and Productivity in Agriculture: Evidence from the Maize Farms in China", American Journal of Agricultural Economics, 101(3): 790-806.

信息科学技术学院电子学系（Department of Electronics）

1．碳纳米管数字电路

彭练矛教授团队发展了一整套无掺杂碳纳米管 CMOS 场效应晶体管技术，成功制备 5 纳米栅长的碳纳米管晶体管；基于高纯半导体碳纳米管薄膜，实现中等规模集成电路，为发展大规模系统奠定了材料和器件基础。

Carbon nanotube digital electronics



Prof. Lianmao PENG and his team examine the development of nanotube-based CMOS field-effect transistors and the different nanotube material systems available to build integrated circuits. We also highlight the medium-scale

integrated circuits created to date and consider the challenges that exist in delivering large-scale systems.

Carbon nanotube digital electronics, Lian-Mao Peng, Zhiyong Zhang and Chenguang Qiu, Nature Electronics 2, 499 (2019).

2. 安全的城域量子密钥分发网络

郭弘教授团队在西安和广州的实际商用光纤上实现了目前世界上传输距离最远的点对点连续变量量子密钥分发，其中传输距离（30 km，50 km）较前提高了 1~2 倍，传输码率（5.77~21.26 kbps）较前提升 100 倍以上，为城域应用铺平了道路。

Secure metropolitan quantum networks move a step closer

Successful new field tests of a continuous-variable quantum key distribution system over commercial fiber networks could pave the way to its use in metropolitan areas. The research team, led by Prof. Hong Guo, carried out two field tests of continuous-variable quantum key distribution over commercial fiber networks in two cities of China - Xi'an and Guangzhou - achieving 6 kbps secret-key-rate over 30.02 km and 49.85 km transmission distances, respectively. Comparing with previous results, these field tests show a more than twice transmission distance, and a two orders-of-magnitude higher secret key rates, though in more lossy commercial fiber links.

Continuous-variable QKD over 50 km commercial fiber, Y. Zhang, Z. Li, Z. Chen, C. Weedbrook, Y. Zhao, X. Wang, Y. Huang, C. Xu, X. Zhang, Z. Wang, M. Li, X. Zhang, Z. Zheng, B. Chu, X. Gao, N. Meng, W. Cai, Z. Wang, G. Wang, S. Yu, H. Guo , Quantum Sci. Technol. 4 035006 (2019)

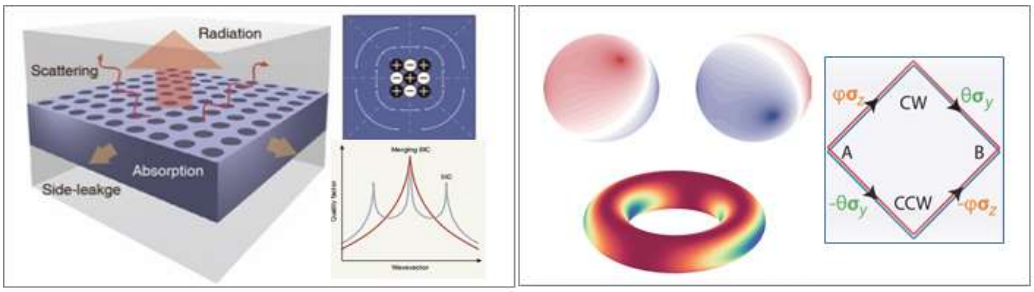
3. 光子学新奇拓扑效应

彭超副教授课题组将拓扑方法应用于光子学领域研究，发现了一系列新奇的物理现象，在增进光子体系内在规律认识的同时有望推动新型光电子器件的发展；运用拓扑荷渐进合并方法，实现了一类对随机散射鲁棒的超高 Q 谐振态，实测 Q 值达创纪录的 49.5×10^5，可大幅提升非线性和量子效应作用强度，在光子集成、量子计算等领域具有重要前景。此外，利用光纤系统中兼并偏振模构造赝自旋基底，首次在实空间中合成并观测了非阿贝尔规范场，为运用光子学方法研究复杂拓扑相

位提供了新途径，为创造可容错的拓扑量子计算平台提供新方法。

Novel topological phenomena in photonics

Topology studies the invariants under continuous deformation. We applied topological concepts upon photonics research and found extraordinary phenomena that broaden the horizon of novel optoelectronic devices. One example is the light trapping through merging a set of topological charges. Ultra-high and scattering-robust optical resonances with record high Q-factor of half-a-million is demonstrated, which could substantially enhance the nonlinear and quantum effects and boost ultra-low-energy lasers towards applications. Besides, we explore a fiber-optic wave system facilitated by time-reversal-symmetry breaking and magnetic nonreciprocity to demostrate Abelian and non-Abelian gauge field synthesis, which could be a promising platform for future topological quantum computation.



Topologically enabled ultrahigh-Q guided resonances robust to out-of-plane scattering, U. Shimanovich, J. Jin, X. Yin, L. Ni, M. Soljačić, B. Zhen, C. Peng, Nature 574, 501–504 (2019)

Synthesis and observation of non-Abelian gauge fields in real space, Y. Yang, C. Peng, D. Zhu, H. Buljan, J. Joannopoulos, B. Zhen, M. Soljačić, Science 365 (6457), 1021-1025, (2019)

信息科学技术学院计算机科学技术系（Department of Computer Science and Technology）

1. AVS2 视频编码标准

高文院士团队主持制定的 AVS2 视频编码国家标准被超高清电视广播采纳。该团队开发了 AVS2 超高清编解码系统，支撑了中央电视台开播 AVS2 超高清频道，2019 年 10 月 1 日保障了我国建国 70 周年庆典和国庆阅兵仪式超高清直播胜利完成。

AVS2 Video Coding Standard

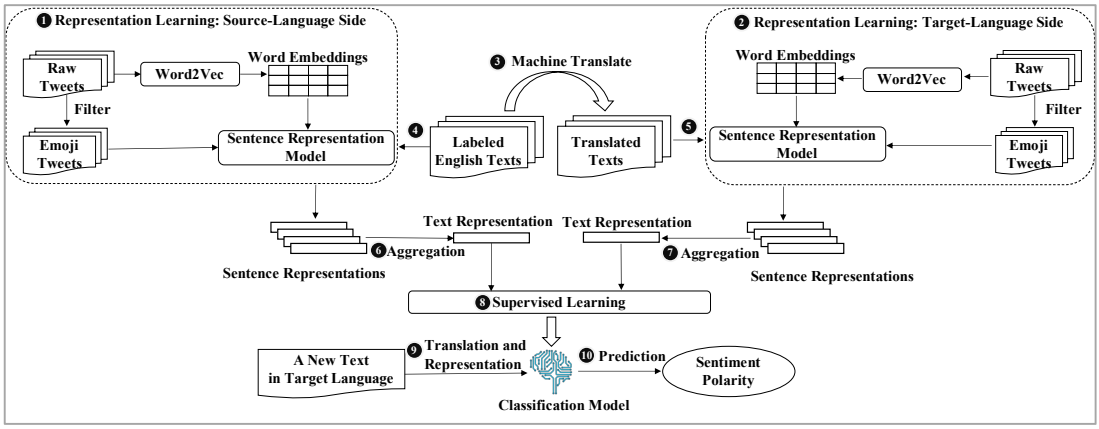
Prof. Wen GAO and his team led the development of video compression standard, AVS2, which was adopted as the national standard for Ultra High Definition TV (UHDTV) broadcasting. We also developed the AVS2 encoding and decoding systems for CCTV (China Central TV Station) to launch UHDTV

channel, which successfully broadcasted the National 70th Anniversary Celebration and Military Parade on Oct. 1, 2019.

2. 基于用户交互绘文字的互联网应用情境解析

数据标注分布不均且有限是严重制约互联网软件情境解析的主要挑战之一。刘譞哲副教授团队提出了一种基于最终用户交互 “绘文字”文本的学习和泛化技术，通过预训练和迁移学习的方式来自动建立数据标签，为大规模场景下的情境解析提出了一种全新思路，提升了情境数据标注的效率、质量和普适性，大规模用户验证后优于目前所有主流方法。该工作在国际万维网大会[1]WWW 2019 的 1608 篇投稿中同行评审总分第一，获得“最佳论文奖”，是该顶级会议历史上，中国科研机构（含港澳台）的唯一一次获奖。

Emoji-powered situation analytics in Internet applications



To tackle the problem of uneven and limited distribution of situational data labels in Internet applications such as Web and Mobile, Associate Prof. Xuanzhe LIU’s research group proposes a novel approach based on representation learning for emojis over interactive texts generated by end-users. This approach can automatically generate situational data labels for users in different languages, and significantly improves the efficiency, quality, and universality of situation analytics in sentiment classification at scale. The paper won the Best Paper Award of World Wide Web Conference 2019, which is the

[1] 该会议由图灵奖获得者、万维网（Web）发明人 Tim Berners-Lee 等人于 1994 年发起创立

breakthrough made by universities and institutions from China in this top conference history.

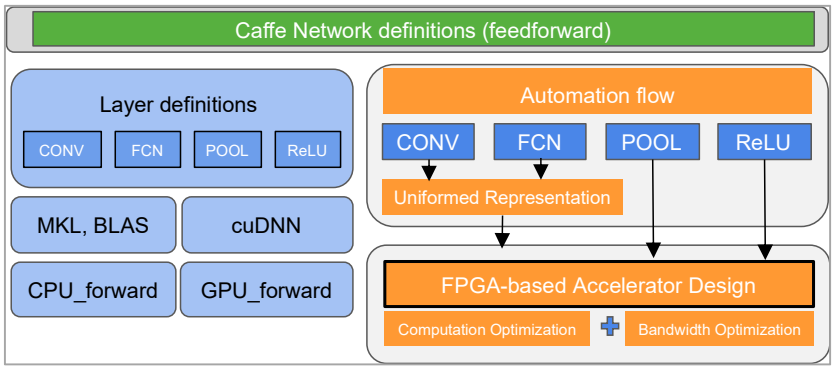
Emoji-powered representation learning for cross-lingual sentiment classification, Zhenpeng Chen, Sheng Shen, Ziniu Hu, Xuan Lu, Qiaozhu Mei, Xuanzhe Liu, The World Wide Web Conference, WWW 2019.

3. Caffeine: 一个基于 FPGA 深度神经网络加速的自动化设计框架

Caffeine 提供了一个软件-硬件协同的设计库，它能够高效地基于 FPGA 对深度神经网络（DNN）进行加速。它采用了统一的矩阵相乘表示方式来描述 DNN 模型中的不同计算层，并且利用扩展后的 roofline 模型来优化加速器架构设计和底层 FPGA 资源利用率。同时，它提供了一个自动化的设计流程，将高层次的 DNN 网络描述直接编译成最终的 FPGA 加速器硬件设计。孙广宇团队的该项工作获得了 IEEE 设计自动化委员会颁发的 2019 Donald O. Pederson 最佳论文奖，这是大陆学者首次获得该奖项。

Caffeine: an automation design framework for accelerating DNN on FPGAs

Caffeine is a hardware/software co-designed library to efficiently accelerate deep neural networks (DNNs) on FPGAs. It uses a uniformed matrix-multiplication representation for different layers in a DNN model. Based on the representation, it optimizes the accelerator microarchitecture and maximizes the underlying FPGA resource utilization based on a revised roofline model. Moreover, it provides an automation flow to directly compile high-level network definitions to the final FPGA accelerator. Guangyu SUN's work has received the 2019 Donald O. Pederson Best Paper Award from the IEEE Council for Design Automation (CEDA). This is the first time for researchers from mainland of China to win the Award.



Caffeine Overview

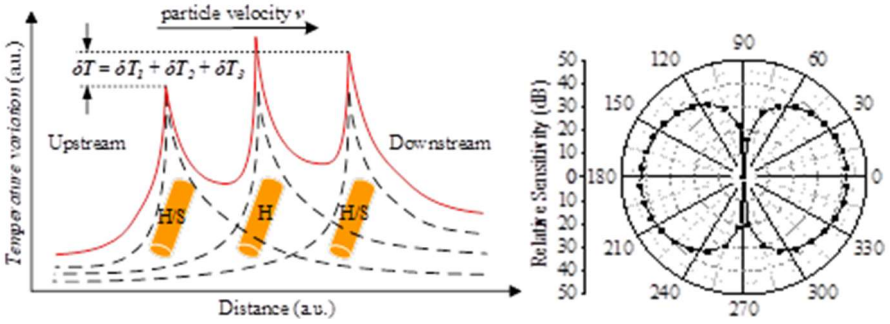
C. Zhang, G. Sun, Z. Fang, P. Zhou, P. Pan and J. Cong, "Caffeine: Toward Uniformed Representation and Acceleration for Deep Convolutional Neural Networks," in IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, vol. 38, no. 11, pp. 2072-2085, Nov. 2019.

信息科学技术学院微纳电子学系(Department of Microelectronics)

1. 新型高灵敏 MEMS 声粒子振速传感器

声粒子振速是声音的矢量特征信号，其能量较低，检测难度非常大。为提高检测能力，高成臣团队提出了一种三热线的检测原理，通过提高检测温敏电阻的自身偏置温度，获得了低噪声、高灵敏检测。

Novel MEMS acoustic particle velocity sensor with high sensitivity



Acoustic particle velocities are vector signals of sound, which are very weak and difficult to be detected conventionally. A novel approach by using microfabricated three-hot-wire is proposed by Prof. Chengchen GAO and his team. Attributed to the elevated temperatures of the sensing thermistors, acoustic particle velocity sensors with both low noise and high sensitivity are achieved.

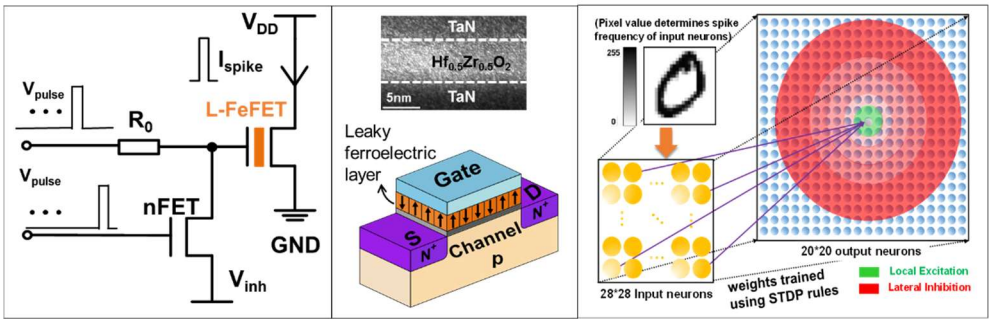
Three-hot-wire acoustic particle velocity sensor with improved detection capability, Li Z , Chang W , Gao C and Hao Y., Electronics Letters, 2019, 55(4):201-202

2. 新型铁电神经形态器件

基于传统 CMOS 实现的神经元需要极高硬件开销，黄芊芊研究员/黄如院士团队提出基于铁电材料设计并实现超低硬件代价的兼备兴奋和抑制连接的随机神经元，为大规模、高集成的低功耗神经形态计算芯片奠定重要基础。

Novel ferroelectric-based neuromorphic devices

For brain-inspired neuromorphic computing, the artificial neurons are still mostly CMOS-implemented and suffer from high-hardware-cost issue. Prof. Qianqian HUANG and Ru HUANG team have proposed and experimentally demonstrated a capacitor-less stochastic neuron based on the novel ferroelectric device with remarkably reduced hardware cost enabling both excitatory and inhibitory input connections, showing the great potential for highly-integrated and low-energy neuromorphic computing system.



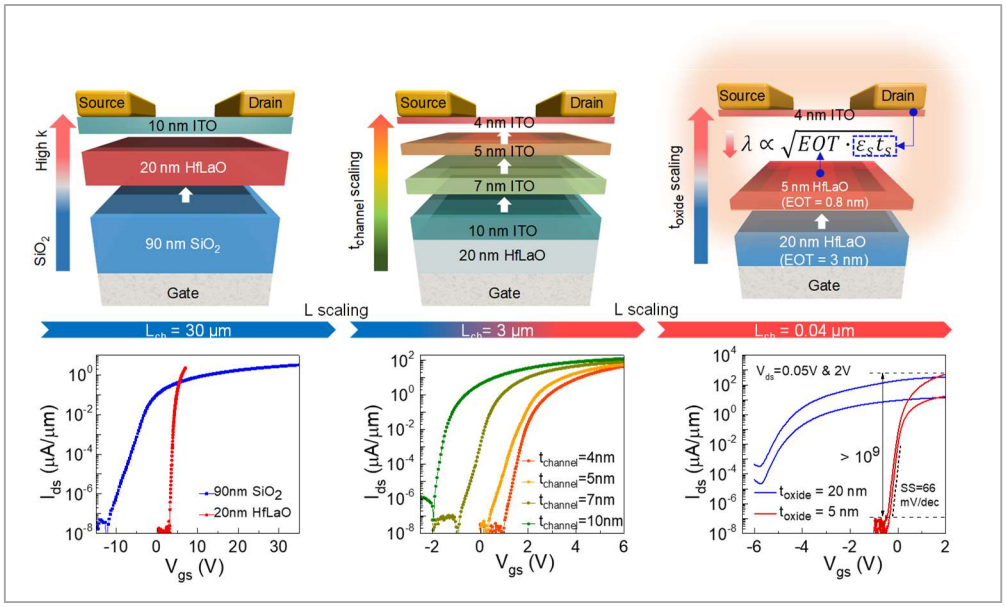
Capacitor-less Stochastic Leaky-FeFET Neuron of Both Excitatory and Inhibitory Connections for SNN with Reduced Hardware Cost, J. Luo, L. Yu, T. Liu, M. Yang, Z. Fu, Z. Liang, L. Chen, C. Chen, S. Liu, S. Wu, Q. Huang, R. Huang, in IEDM Tech. Dig., 2019, pp 122-125.

3. 基于超薄氧化铟锡的高性能超低功耗晶体管

基于量子限域效应的半导体性超薄氧化铟锡沟道，吴燕庆团队实现了高性能亚 100 nm 晶体管，开关比超过国际最高水平 10 倍以上。其开态电流、射频性能、反相器增益均远超同类器件。其优异的微缩能力可用于未来 5nm 工艺节点的高性能超低功耗半导体器件。

High performance transistor based on ultrathin indium tin oxide with extremely low power

The previously metallic indium tin oxide can be energy-band engineered into high performance sub-100 nm transistors with high on-off ratio, 10 times higher than previous record. The on-state current, radio frequency performance as well as logic inverter gains are also much higher than previous results. The unique wide bandgap and low dielectric constant of ITO provide prospects for future scaling below the 5-nm regime for advanced low-power electronics.



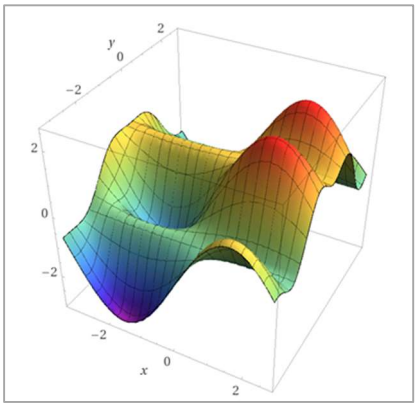
Shengman Li, Mengchuan Tian, Qingguo Gao, Mengfei Wang, Tiaoyang Li, Qianlan Hu, Xuefei Li & Yanqing Wu, "Nanometre-thin indium tin oxide for advanced high-performance electronics", Nature Materials 18, 1091–1097 (2019)*

信息科学技术学院智能科学系（Department of Machine Intelligence）

1．梯度下降法求出深度神经网络的全局极小值

深度学习是当前人工智能的核心技术。长久以来，深度神经网络的训练被认为是非凸优化问题，从而受到局部极值的困扰。王立威团队首次证明，对充分过参数化的深度神经网络，尽管全局非凸，但局部近似凸优化，且包含全局最优点；从而进一步证明了一阶优化算法可在多项式时间内达到全局最优。

Gradient Descent Finds Global Minima of Deep Neural Networks



Gradient descent finds a global minimum in training deep neural networks despite the objective function being non-convex. The current paper proves gradient descent achieves zero training loss in polynomial time for a deep overparameterized neural network with residual connections (ResNet). Prof. Liwei WANG team's analysis relies on the particular structure of the Gram matrix induced by the neural network architecture. This structure allows us to show the Gram matrix is stable throughout the training process and this stability implies the global optimality of the gradient descent algorithm. We further extend our analysis to deep residual convolutional neural networks and obtain a similar convergence result.

Gradient Descent Finds Global Minima of Deep Neural Networks, Simon S.Du[1], Jason D.Lee*[2],Haochuan Li*[3 4],Liwei Wang*[5 4],Xiyu Zhai*[6], International Conference on Machine Learning(2019).*

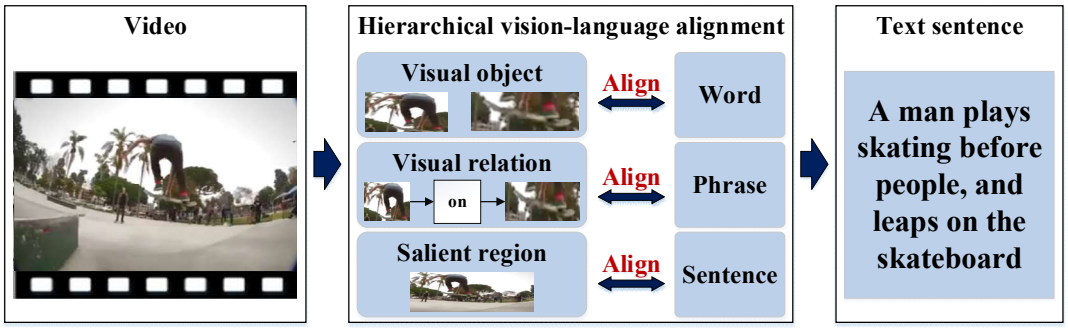
王选计算机研究所（Wangxuan Institute of Computer Technology）

1．层次化视觉-语言对齐的视频描述生成

视频描述生成是指计算机自动生成描述视频内容的文本语句，关键问题是如何建模视频内容与文本语句之间的语义一致性。彭宇新团队提出层次化视觉-语言对齐，学习多粒度的视觉-语言隐含对齐信息，通过二元记忆循环网络层次化地指导生成准确的文本语句。

Hierarchical vision-language alignment for video captioning

Video captioning is to generate sentences for describing the video content, for which the key problem is to model the semantic correspondences between video content and language sentence. This paper, by Prof. Yuxin PENG and his team, proposes the hierarchical vision-language alignment approach, which learns multi-granularity latent vision-language alignment information, and exploits dual-memory recurrent network to provide hierarchical semantic guidance for accurate sentence generation.



Hierarchical Vision-Language Alignment for Video Captioning, Junchao Zhang and Yuxin Peng, 25th International Conference on MultiMedia Modeling (MMM), pp. 42-54, 2019. (Best Paper Award)*

2. 小柯：面向科学新闻的 AI 写作机器人

万小军团队成功研制了跨语言新闻生成系统-小柯，该系统能够基于世界顶级英文科技论文自动生成中文科学新闻，报道最新科技进展。系统采用的核心技术为自然语言生成与机器翻译，解决了两个技术难题：1）面向科技文本的机器翻译质量较差；2）新闻报道与科技论文的语言风格不同。系统已部署在中国科学报社科学网，是业界首个跨语言科技新闻写作机器人。

小柯访问地址: http://news.sciencenet.cn/AInews/

Xiaoke: An AI Writer of Science News

Prof. Xiaojun WAN and his team have successfully developed a cross-language news generation system – Xiaoke, which can automatically generate scientific news stories about the latest discoveries from the world's leading science journals. The system was built upon natural language generation and machine translation techniques, and it has addressed two technical challenges of low

machine translation quality for scientific texts and inconsistent language styles between news articles and scientific papers. The system has been deployed in China Science Daily and it is the first cross-language AI reporter for science news.

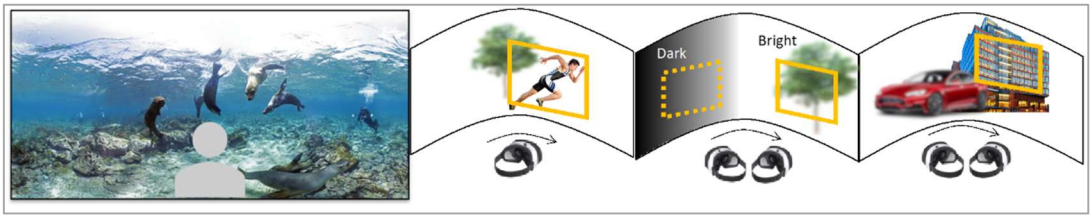
Visit Xiaoke here: http://news.sciencenet.cn/AInews/

3. 人眼视觉感知的虚拟现实视频传输

虚拟现实视频可提供远程交互和沉浸式体验，正在改变我们的世界。张行功团队研究了人眼对虚拟现实视频质量感知的机理，利用人眼感知特性提高虚拟现实视频的远程传输质量。

Human Perception Streaming of Virtual Reality Video

Virtual reality videos are making our world more and more virtual, which provide remote interactions and immersive visual experiences. Prof. Xinggong ZHANG and his team are exploiting the human visual perception to improve the quality of virtual reality video streaming over Internet.

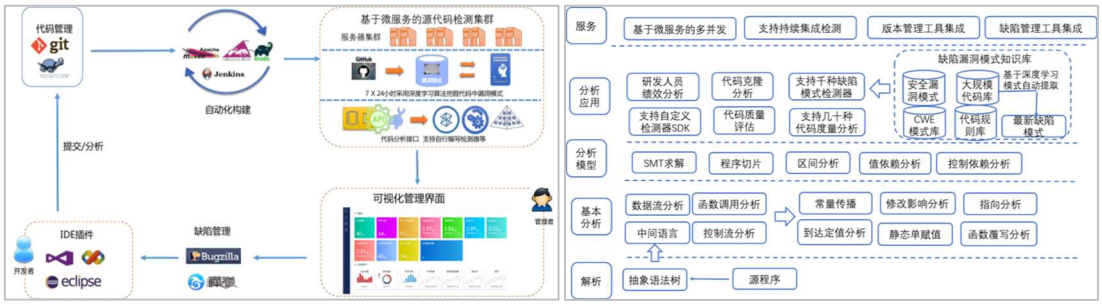


Pano: optimizing 360° video streaming with a better understanding of quality perception, Y. Guan, C. Zheng, X. G. Zhang, Z. M. Guo, J. C. Jiang, In Proceedings of the ACM SIGCOMM, August 2019, NY, USA, 394–407.*

软件工程国家工程研究中心（National Engineering Research Center for Software Engineering）

1. 高精度软件安全分析技术

张世琨研究员、马森副研究员和高庆助理研究员研究组在源代码安全分析领域，针对代码分析精度和效率折衷问题，提出了一种基于值依赖分析的迭代求精分析技术，分析算法能够根据程序的复杂度进行更好的精度与效率的平衡，应用该方法研发了库博软件源代码分析工具，已经在上百家企业得到应用，打破了国外工具在该领域的垄断；在软件同源分析方面，提出了一种分级多特征的同源检测方法，研发了库博软件成分分析工具，检测精度得到明显提升，整体检测精度超过了国外同类商业工具。曾获日内瓦国际发明展金奖和阿里巴巴软件供应链大赛（软件后门自动检测比赛）第一名。



High precision software security analysis technology

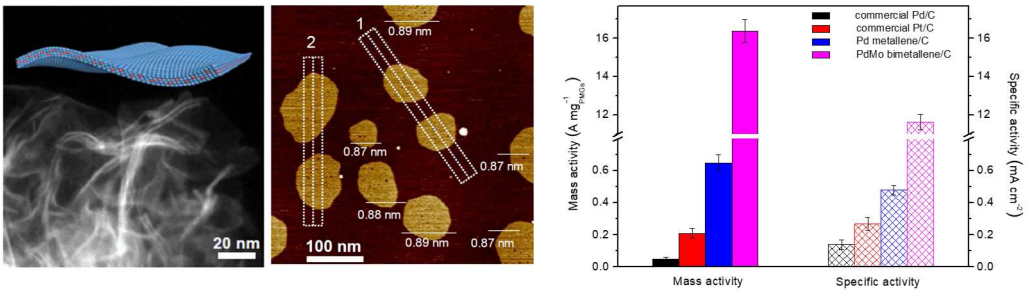
In the field of source code analysis, we proposed an iterative refinement analysis technology based on value dependence analysis. The analysis algorithm has better balanced between the accuracy and efficiency according to the complexity of the program. Leveraging our technologies, we developed the source code analysis tool, called CoBOT, which has been applied in hundreds of enterprises, and breaks the monopoly of foreign counterpart tools. In the field of software components analysis, we propose a novel hierarchical and multi-feature detection method, which significantly improves the detection accuracy. In the past few years, we won the gold medal of Geneva International Invention Exhibition, and first prize in Alibaba software supply chain competition.

工学院（College of Engineering）

1．钯钼双金属烯显著提升燃料电池和锌空电池氧反应催化性能

郭少军团队在国际上首次报道了亚纳米厚且高度几何卷曲的钯钼双金属烯材料，发现其在碱性下可显著提升氧还原和氧析出反应的活性和稳定性，并在锌空电池器件中展现很好的催化性能。并首次发现了双金属烯材料的合金效应、应变效应和量子效应可调控金属烯体系的电子结构，实现显著增强的催化性能。

PdMo Bimetallene Boosts Oxygen Catalysis in Fuel Cells and Zn-air Battery



Prof. Shaojun GUO and his team demonstrate that PdMo bimetallene, a palladium–molybdenum alloy in the form of a highly curved and sub-nanometre-thick metal nanosheet, can greatly boost the electrocatalysis of the oxygen

reduction reaction and oxygen evolution reaction in alkaline electrolytes, and shows very good catalytic performance in Zn–air batteries. We first realize that the alloying effect, strain effect, and quantum size effect from PdMo bimetallene can tune the electronic structure of the system for greatly enhanced catalytic performance.

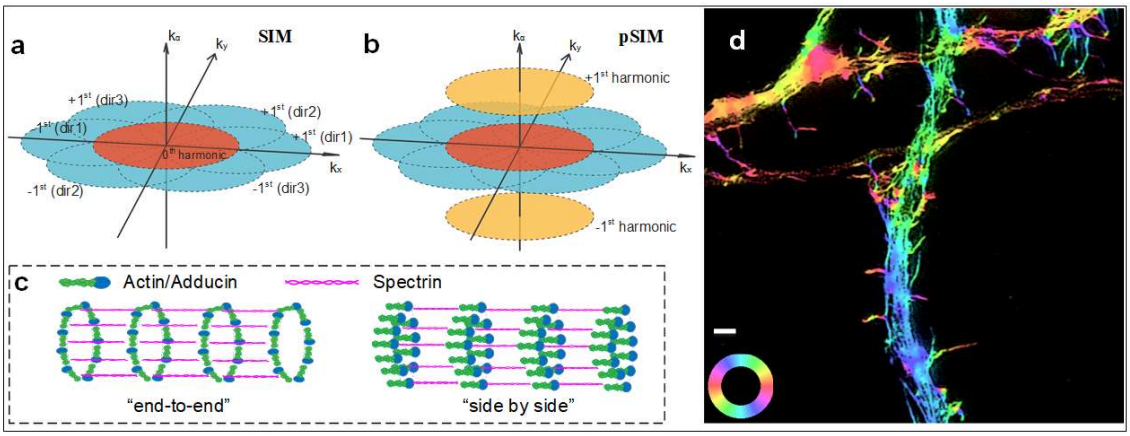
Bimetallene for Oxygen Reduction Catalysis, M. Luo, Z. Zhao, Y. Zhang, Y. Sun, Y. Xing, F. Lv, Y. Yang, X. Zhang, S. Hwang, Y. Qin, J. Ma, F. Lin, D. Su, G. Lu and S. Guo, Nature 2019, 574, 81.*

2. 偏振结构光显微技术

席鹏团队研发的偏振结构光照明显微（pSIM）通过在高维复合空间提取偶极子信息，可直接与商用的 SIM 成像系统结合，适用于多种成像模式。pSIM 揭示了神经元轴突中细胞骨架的“并排”组装新模型，推翻了以往教科书的“端到端”组装结构假设。

Super-resolution imaging of fluorescent dipoles via polarized structured illumination microscopy

Polarized structured illumination microscopy (pSIM), developed by Prof. Peng XI and his team, achieves super-resolution imaging of dipoles by interpreting the dipoles in spatio-angular hyperspace and applies directly to a large variety of commercial and home-built SIM systems with various imaging modality. pSIM was demonstrated on multiple biological applications and revealed “side-by-side” assembly of actin-ring structure in neuronal axons, which has revised the textbook “side-by-side” prediction.



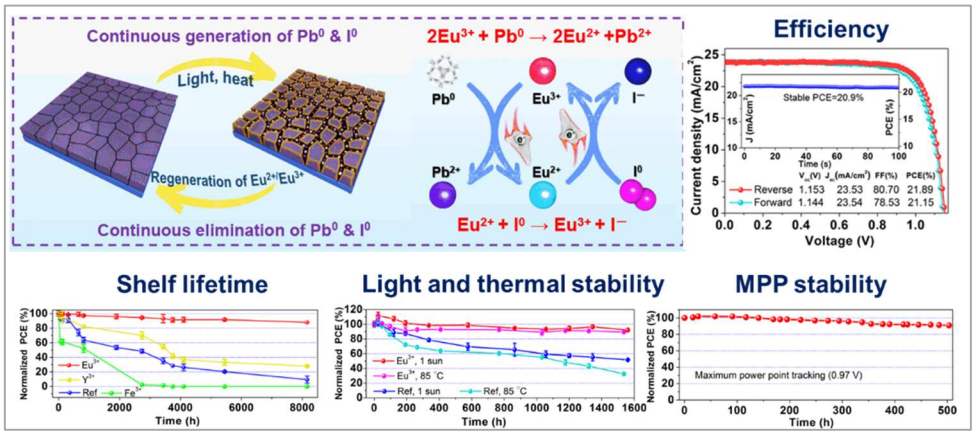
Super-resolution imaging of fluorescent dipoles via polarized structured illumination microscopy, K. Zhanghao, X. Chen, W. Liu, M. Li, Y. Liu, Y. Wang, S. Luo, X. Wang, C. Shan, H. Xie, J. Gao, X. Chen, D. Jin, X. Li, Y. Zhang, Q. Dai* and P. Xi*, Nature Communications 10, 4694 (2019).*

3. 离子氧化还原梭大幅提升钙钛矿太阳能电池的工作稳定性

周欢萍团队和化学与分子工程学院严纯华/孙聆东团队合作提出在钙钛矿太阳能电池中创造性地引入铕离子对，通过氧化还原反应循环修复了铅卤钙钛矿中的零价铅和零价碘缺陷对，大幅提升了太阳能电池的使用寿命和稳定性。

Improving the operational stability of perovskite solar cells by an ion redox shuttle

Prof. Huanping ZHOU's team and Prof. Chunhua YAN/Lingdong SUN's team collaborate to show that the europium ion pair Eu^{3+}-Eu^{2+} acts as the "redox shuttle" that selectively oxidized Pb^0 and reduced I^0 defects in Pb-I perovskite materials simultaneously in a cyclical transition. It therefore significantly improves the operational durability and stability of perovskite solar cells.



A Eu^{3+}-Eu^{2+} ion redox shuttle imparts operational durability to Pb-I perovskite solar cells. Ligang Wang, Huanping Zhou, Junnan Hu, Bolong Huang, Mingzi Sun, Bowei Dong, Guanghaojie Zheng, Yuan Huang, Yihua Chen, Liang Li, Ziqi Xu, Nengxu Li, Zheng Liu, Qi Chen, Ling-Dong Sun*, Chun-Hua Yan*, Science, 2019, 363, 265-270.*

心理与认知科学学院（School of Psychological and Cognitive Sciences）

1. 人脑中特征注意的“节奏探照灯”模型

当注意加工资源集中于某个非空间特征（颜色、朝向、运动方向等）的时候，个体对整个视野范围内所有包含了目标特征的视觉客体的感知都会变得更加敏锐。这种注意过程被称为基于特征的注意（feature-based attention）。大脑如何同时注意多个视觉特征是视觉科学领域所关心的重大问题。本研究通过重建人脑同时注意多个特征时的神经表征，首次揭示了注意在特征空间的“节律性探照灯”加工模式。

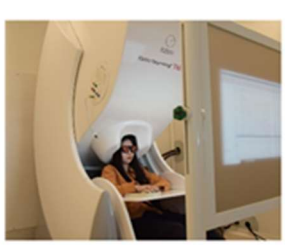


图 1：北京大学脑磁图数据采集系统

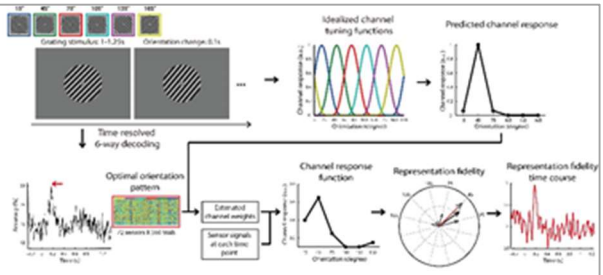


图 2：基于 IEM 重构朝向表征的动态变化过程

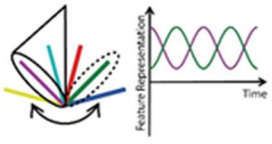


图 3：特征空间中的“节律性探照灯”

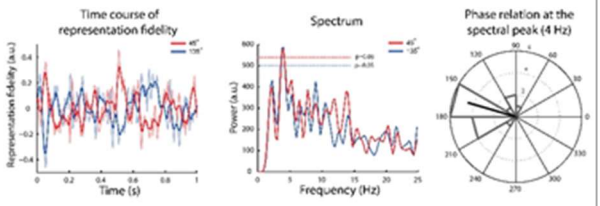


图 4：朝向表征的时间动态变化

Competing rhythmic neural representations of orientations during concurrent attention to multiple orientation features

How the brain concurrently attends to multiple features remains unknown and cannot be easily deduced from classical attention theories. A rhythm-based, time-multiplexing neural machinery underlying concurrent multi-feature attention was suggested.

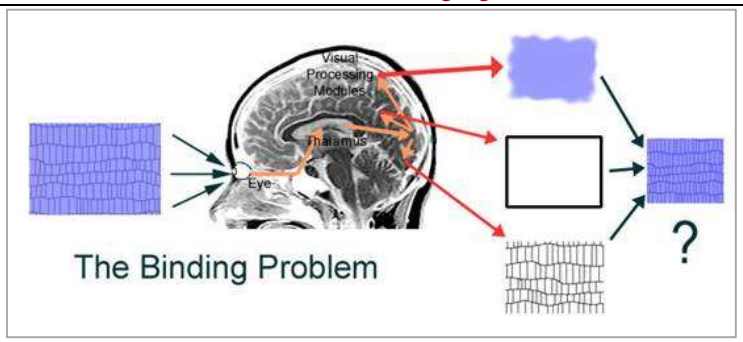
Mo, C., Lu, J., Wu, B. et al. Competing rhythmic neural representations of orientations during concurrent attention to multiple orientation features. Nature Communication, 10, 5264 (2019). https://doi.org/10.1038/s41467-019-13282-3

2. 视觉特征绑定的神经机制

人类视觉系统在知觉外部世界的过程中，遵循着先分解，再组合的原则，即外部物体的视觉输入信息首先会被分解成不同的特征，如形状、颜色、运动等，这些特征会分别在不同的脑区进行加工，随后被整合到一起，形成对物体统一的知觉。这一整合过程的神经机制，被称为特征的绑定问题(the binding problem)，是视觉科学乃至整个脑科学领域中最令人费解的核心问题之一。方方团队的研究借助脑电图记录和经颅交流电刺激的方法，探讨了 alpha 振荡在视觉特征绑定过程中的关键作用，为揭示特征绑定的神经机制方面做出了重要贡献。

The causal role of alpha oscillations in feature binding

Integrating visual features into a coherent scene is a challenge for the visual system known as the binding problem. Brain oscillations in the γ-band have been suggested to be a neural substrate of feature binding. Using electroencephalogram, it is found that feature binding was closely associated with α-oscillations. Through the entrainment of α-oscillations by transcranial alternating current stimulation, selectively changing α-oscillations could shape feature binding.



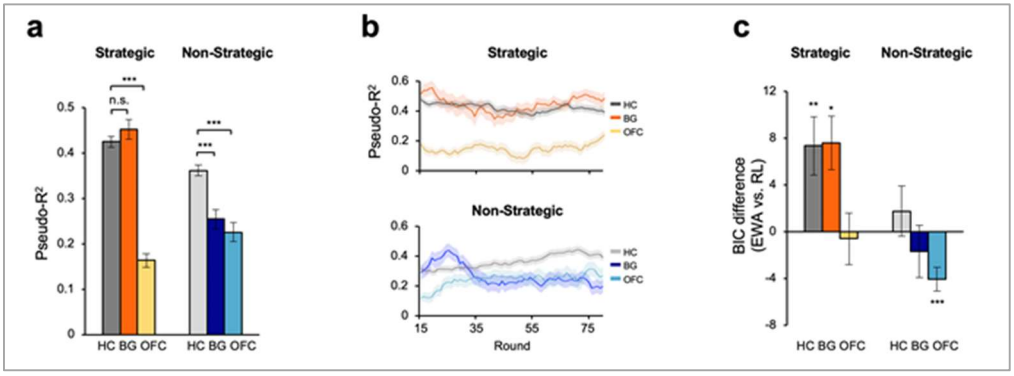
Zhang, Y., Zhang, Y., Cai, P., Luo, H., & Fang, F. (2019). The causal role of alpha-oscillations in feature binding. Proceedings of the National Academy of Sciences of the United States of America, 116(34), 17023-17028. doi:10.1073/pnas.1904160116

3. 社会学习决策的计算神经机制

大脑基底神经节（basal ganglia)是位于大脑深部的神经核团，接受多巴胺神经元的投射，在运动、奖赏、强化学习和决策等众多领域都起着关键作用。有趣的是，基底神经节受损之后，虽然很多基本的决策功能会遭到损坏，但是一些看起来更高等、更复杂的社会决策能力却得以幸免，表现出一定的“韧性（”resilience”）。本研究利用较罕见的基底神经节局部受损的病人，结合经济学中的博弈实验和计算建模等方法，研究了基底神经节受损之后，大脑何如通过调用基于其他脑区的“计算程序”，处理相关社会信息，来弥补被破坏的强化学习能力。这一发现从因果关系的角度说明，社会决策可能依赖于强化学习和高等学习的并行支持。

Patients with basal ganglia damage show preserved learning in an economic game

Both basal ganglia (BG) and orbitofrontal cortex (OFC) have been widely implicated in social and non-social decision-making. However, unlike OFC damage, BG pathology is not typically associated with disturbances in social functioning. The paper provides the first study reconciling these differences by studying the causal contribution of BG to an important class of social decisions captured by economic games. Specifically, combining neuroeconomic and computational approaches, its results suggest that preserved social decision-making capacity in BG pathologies reflects compensatory effects of high-order, model-based systems which are not dependent on BG integrity.



Zhu, L., Jiang, Y., Scabini, D. et al. Patients with basal ganglia damage show preserved learning in an economic game. Nature Communication, 10, 802 (2019). https://doi.org/10.1038/s41467-019-08766-1

城市与环境学院（College of Urban and Environmental Sciences）

1．揭示污染物排放引发全球变暖以及植被生态响应中的非线性过程

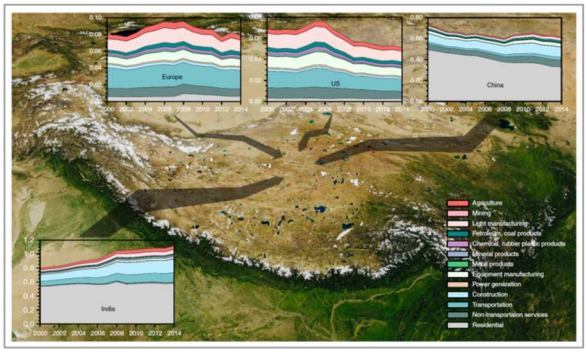
刘峻峰团队研究结果表明，国际贸易加剧了青藏高原冰川地区的 BC 污染，并可能导致严重的气候变化。全球需要进一步加强对相关地区（特别是南亚地区）黑炭排放的管控，从而减轻黑炭对青藏高原的气候威胁。

刘鸿雁团队研究揭示了干旱区森林对于极端湿润和干旱事件的对称响应规律，提升了人们对于森林响应极端气候事件的认识，为改进陆面模型提供了理论基础。

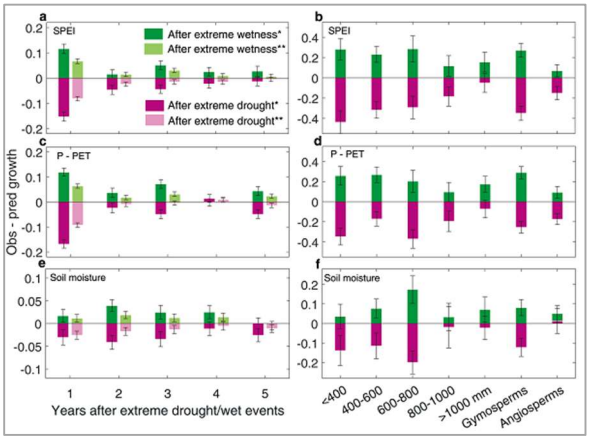
朴世龙团队研究发现，尽管植被生长季绿度和物候都有着清晰海拔梯度变化，但在时间维度上，并未发现不同海拔植被生长季绿度均匀化和物候同步性提高的普遍现象。上述发现为深入理解气候变化对植被生长垂直分布规律的影响提供了重要支撑。

Reveal the non-linear processes in the global warming caused by pollutant emissions and the ecological response of vegetation

The research results of Junfeng LIU's group show that international trade has exacerbated BC pollution in the glacial area of the Qinghai-Tibet Plateau and may cause severe climate change. The world needs to further strengthen the control of black carbon emissions in relevant regions (especially South Asia), so as to reduce the climate threat of black carbon to the Tibetan Plateau.

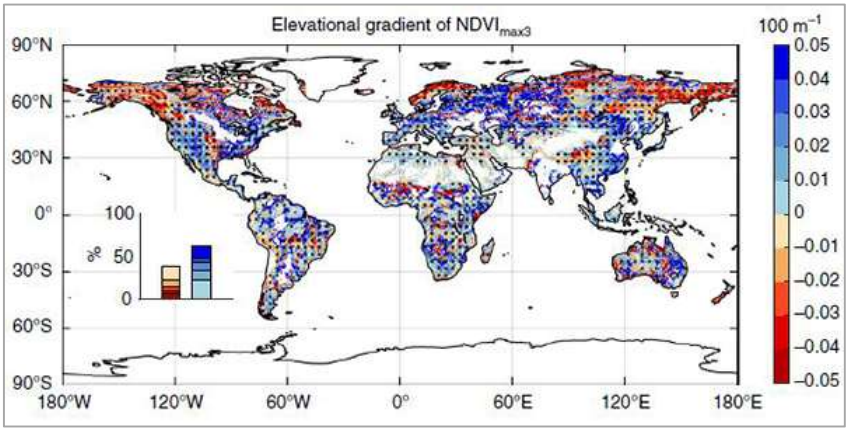


Hongyan LIU's team systematically studied the response of forest productivity to extreme humid events. The results show that after experiencing extreme humid events, the forest has a growth acceleration that lasts 1 to 5 years, and generally compensates for the effects of extreme drought events, and this compensation effect is particularly obvious in forests in arid and semi-arid areas. This study revealed the symmetrical response law of forests in arid regions to extreme humid and



drought events, raised people's understanding of forests' response to extreme climate events, and provided a theoretical basis for improving land surface models.

Shilong PIAO's team analyzed changes in the elevational patterns of vegetation greenness, spring and autumn phenology in the global vegetation growth season over the past three decades. The study found that although the greenness and phenology of the vegetation growth season have clear changes in altitude gradients. No universal phenomenon of uniformity of greenness and improvement of phenology synchronization in vegetation growth season at different altitudes along time has been found. The above findings provide important support for understanding the impact of climate change on the vertical distribution of vegetation growth.



The cascade of global trade to large climate forcing over the Tibetan Plateau glaciers. Yi, K; Meng, J; Yang, HZ; He, CL; Henze, DK.; Liu, JF; Guan, DB; Liu, Z; Zhang, L; Zhu, X; Cheng, YL; Tao, S, Nature Communications 10 3281(2019)

Enhanced growth after extreme wetness compensates for post-drought carbon loss in dry forests. Peng, J; Liu, HY; Piao, SL; Ciais, P; Wu, XC; Yin, Y; Wang, HY, Nature Communications 10 195(2019)

Divergent changes in the elevational gradient of vegetation activities over the last 30 years. Gao, MD; Piao, SL; Chen, AP ; Yang, H; Liu, Q; Fu, YSH; Janssens, IA, Nature Communications 10 2970(2019)

2. 揭示了人类活动引发的全球尺度环境污染与健康效应

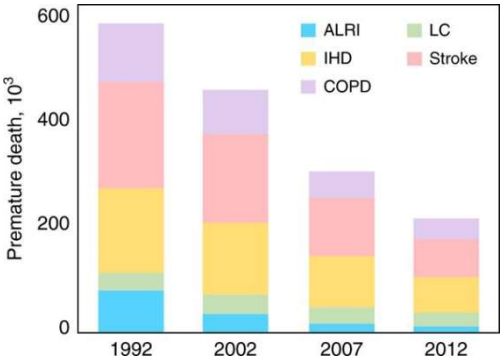
沈国锋课题组依托北京大学团队自己建立的全球高分辨大气污染物排放清单，基于最新调查获得农村居民生活能源结构和消耗量数据，研究组系统评估了中国农村生活能源转型带来的环境、健康和气候效应。该研究为全面而客观地认识生活能源对大气环境与健康的影响提供了重要的价值。

王学军课题组以水稻的生命周期为基础，定量阐述了水稻中的汞如何在全球范围内与人类健康和环境系统的相互作用。研究发现，水稻可能也是全球人类甲基汞暴露的显著膳食来源，尤其是在南亚和东南亚。国际水稻贸易引发人类甲基汞暴露风险的区域转移，并显著加剧了非洲、中亚和欧洲的甲基汞暴露风险。世界上大多数地区居民因食用水稻而摄入的甲基汞不会超过鱼类，然而，在亚洲许多以稻米为主

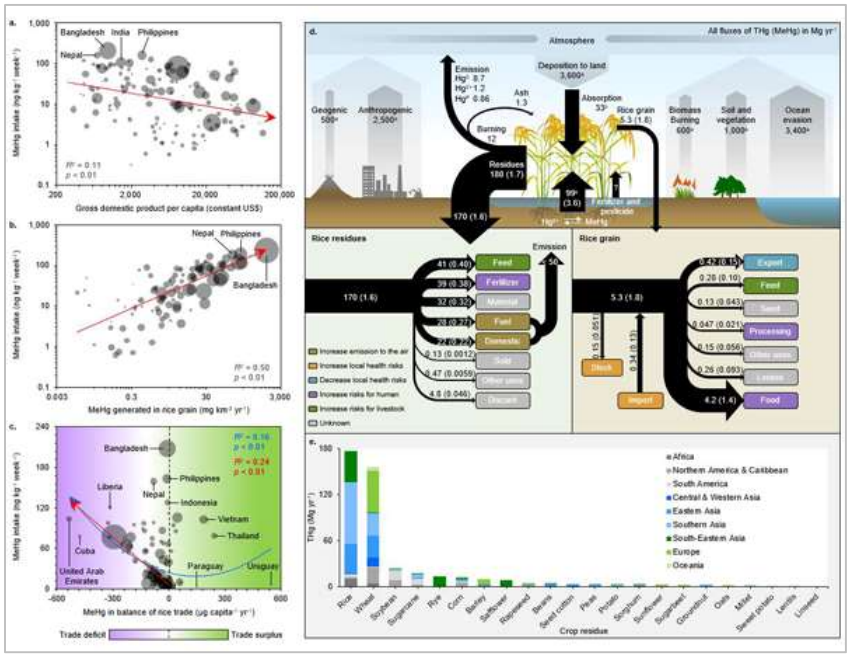
食的土壤污染地区，水稻和鱼类共同消费导致的甲基汞暴露可能成为一个重要的健康问题。

Reveals global-scale environmental pollution and health effects caused by human activities

Guofeng SHEN's team systematically assessed the environment, health, and climate effects caused by the transformation of rural living energy, using the global high-resolution air pollutant emission inventory established by the Peking University team, and the latest survey data on the energy structure and consumption of rural residents. This research is valuable for a comprehensive and objective understanding of the impact of living energy on the atmospheric environment and health.



Based on the life cycle of rice, Xuejun WANG's group quantitatively explained how the mercury in rice interacts with human health and environmental systems on a global scale. Studies have found that rice may also be a significant dietary source of global human methylmercury exposure, especially in South and Southeast Asia. The international rice trade has triggered regional shifts in human methylmercury exposure and has significantly increased the risk of methylmercury exposure in Africa, Central Asia and Europe. In most areas of the world, residents will not consume more methylmercury than rice due to rice consumption. However, in many soil-contaminated areas where rice is the staple food in Asia, methylmercury exposure caused by joint consumption of rice and fish may become an important health issue.



Impacts of air pollutants from rural Chinese households under the rapid residential energy transition. Shen, GF ; Ru, MY; Du, W; Zhu, X; Zhong, QR ; Chen, YL ; Shen, HZ ;Yun, X ; Meng, WJ; Liu, JF ; Cheng, HF ; Hu, JY ; Guan, DB ; Tao, S, Nature Communications 10 3405(2019)

Rice life cycle-based global mercury biotransport and human methylmercury exposure. Liu , MD; Zhang, QR; Cheng, MH; He, YP; Chen, L; Zhang, HR; Cao, HL; Shen, HZ; Zhang, W; Tao, S; Wang, XJ, Nature Communications 10 5164(2019)

3. 方精云院士获美国生态学会惠特克杰出生态学家奖

2019 年 4 月 16 日，城市与环境学院/生态研究中心方精云院士因“在推动生态学发展、服务国家和国际政策制定以及建立生态学共同体方面的杰出贡献”获 2019 年度“惠特克杰出生态学家奖”。“惠特克杰出生态学家奖”由美国生态学会设立，以纪念享誉世界的杰出生态学家罗伯特·惠特克，授予对生态学做出突出贡献的非美籍生态学家，每年仅有一名生态学家入选，是国际生态学界最具影响的奖项之一。方精云是获得该奖的第一位中国人。

Academician Jingyun FANG received the Whitaker Distinguished Ecologist Award

On April 16, 2019, Prof. Jingyun FANG, College of Urban and Environmental Sciences / Ecology Research Center, won the Outstanding Ecologist Award "Whitaker of 2019" for his "outstanding contribution to promoting ecological development, serving national and international policy formulation, and establishing an ecological community." The Whitaker Distinguished Ecologist Award was established by the Ecological Society of America in honor of the world-renowned distinguished ecologist Robert Whitaker, and awarded to non-American ecologists who have made outstanding contributions to ecology. The selection of ecologists is one of the most influential awards in the international ecological community. Prof. Jingyun FANG was the first Chinese to win the award.

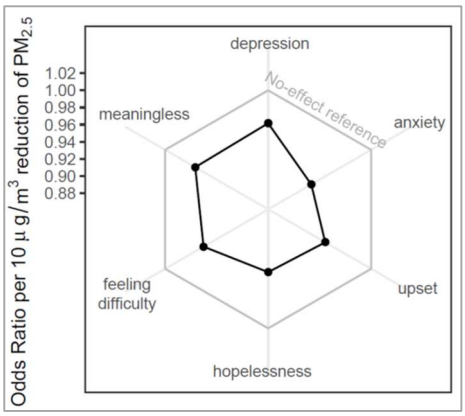
环境科学与工程学院（College of Environmental Sciences and Engineering)

1. 环境因素能够影响精神健康

环境因素能够通过生理和心理学机制影响人群心理健康。基于中国人群数据，朱彤团队检验了多种环境因素与健康的联系。研究发现，空气污染和气温波动会导致成人精神健康的恶化；人居环境绿地可能会改善精神健康。

Mental health impacts from environment

Environmental factors can affect human mental health through physiological and psychological pathways. Prof. Tong ZHU and his team explored the associations between mental health and a few environmental factors among a nationally representative sample of Chinese adults. We found air pollution and temperature variation were associated to declined mental health. Residential greenness might be associated to better mental health.



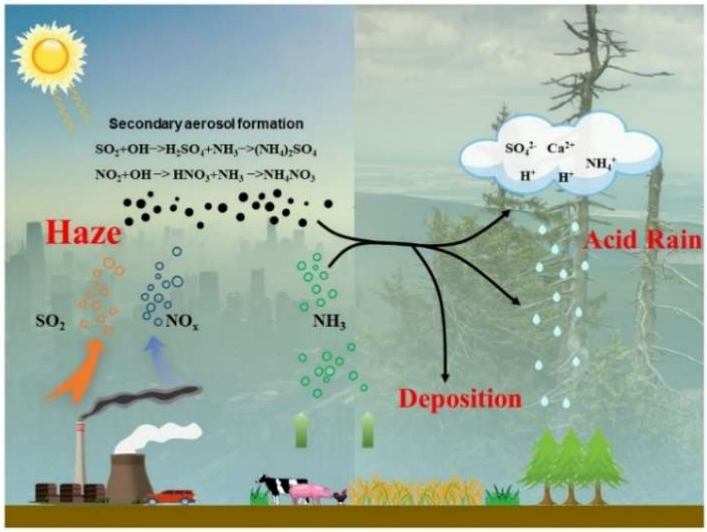
Declines in mental health associated with air pollution and temperature variability in China. Xue T, Zhu T, Zheng Y, Zhang Q. Nature Communications 10 2165 (2019).

2. 我国控制氨气排放的复杂环境影响

氨气在大气环境和生态系统中扮演着十分重要的角色， 包括形成灰霾、中和酸雨以及影响全球氮循环。宋宇团队研究定量评估了氨气排放的复杂环境效应，提出我国需要依据环境和生态效应分区域制定氨减排计划。

Complex effects of ammonia emission control in China

Atmospheric ammonia (NH3) plays key roles in haze formation, neutralization of acid rain, and global nitrogen cycle. Prof. Yu SONG and his team evaluate the complex environmental effects caused by NH3 emissions and propose a targeted NH3 emission control strategy in the agricultural sector for China.



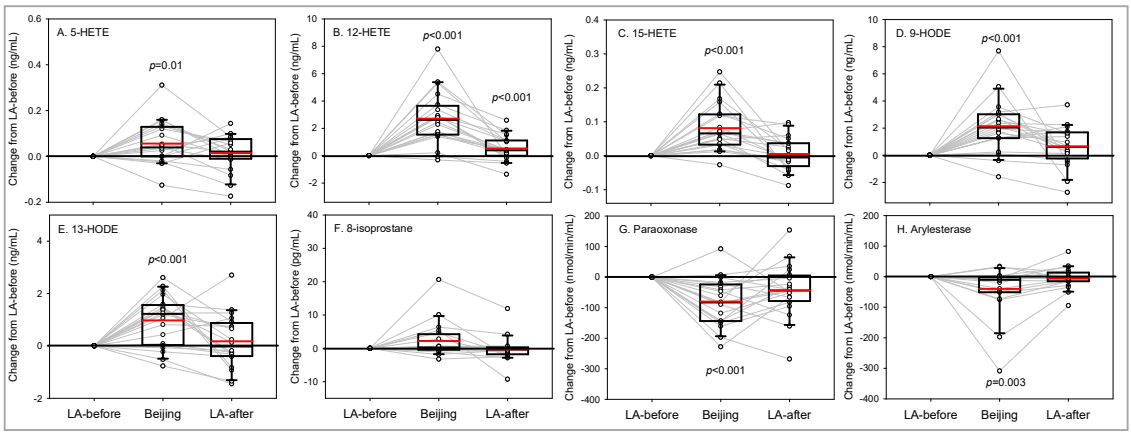
Ammonia emission control in China would mitigate haze pollution and nitrogen deposition, but worsen acid rain, M. Liu, X. Huang, Y. Song et al., Proceedings of the National Academy of Sciences of the United States of America, 116 (16) 7760-7765 (2019)

3. 由洛杉矶到北京的促氧化应激和促炎效应：基于生物标志物的自然控制实验

针对大气污染诱发心血管疾病的早期效应这一重要科学问题，邱兴华团队与洛杉矶加州大学合作，利用中美污染的空间差异构建自然暴露控制实验，发现在高污染环境中，脂氧合酶激活和过氧磷酶抑制是心血管效应的关键机制，深化了对促氧化和促炎机制的认识，并确认具有潜在临床价值的新型心血管效应标志物。

Pro-Oxidative and Proinflammatory Effects After Traveling From Los Angeles to Beijing A Biomarker-Based Natural Experiment

Focusing on the early cardiovascular effect of air pollution exposure, Xinghua QIU's group cooperated with UCLA, and designed a novel natural exposure control experiment on young healthy travelers from Los Angeles to Beijing. In correspondence to higher exposure in Beijing, activation of lipoxygenase and inhibition of paraoxonase were found the key mechanism of early cardiovascular effect, therefore deepened our understanding on air pollution induced cardiovascular diseases with pro-oxidation and pro-inflammatory mechanism. In addition, this study proposed a series of novel biomarkers on such effect with potential clinical application value.



Changes in concentrations of circulating biomarkers of lipid peroxidation and paraoxonase-1 activity among the 3 phases of the study.

Pro-oxidative and pro-inflammatory effects after traveling from Los Angeles to Beijing: A biomarker-based natural experiment, Y. Lin, G. Ramanathan, Y. Zhu, F. Yin, N.D. Rea, X. Lu, C.-H. Tseng, K. F. Faull, A. J. Yoon, M. Jerrett, T. Zhu, X. Qiu*, J. A. Araujo*, Circulation 140, 1995-2004 (2019).*

前沿交叉研究院（Academy for Advanced Interdisciplinary Studies）

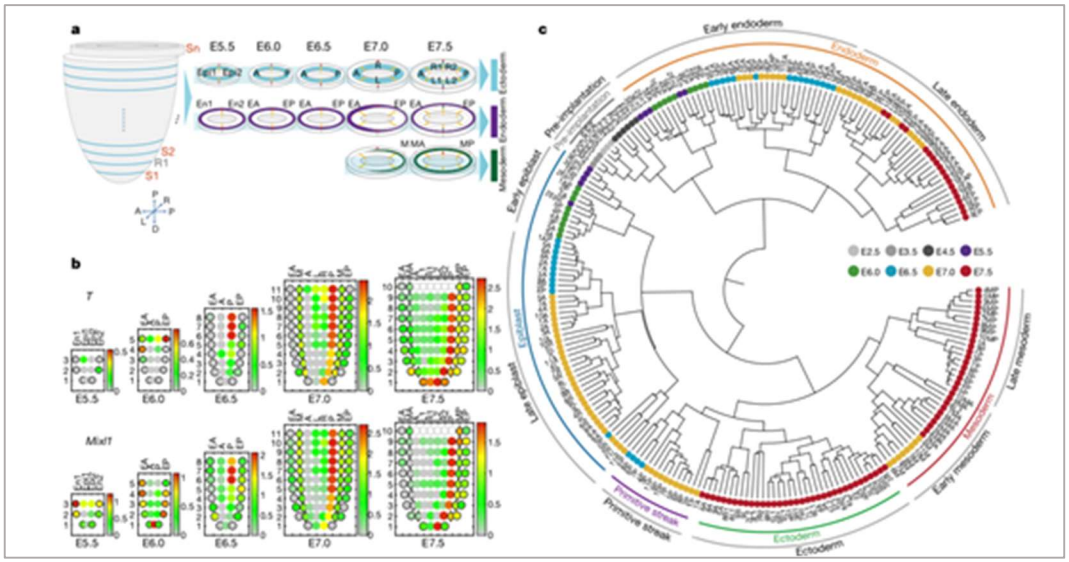
1. 首次构建小鼠早期胚胎着床后发育时期高分辨率时空转录组图谱

韩敬东教授团队报告了从原肠胚前期到晚期原肠胚阶段发育过程中胚层中确定位

置的细胞群的空间分辨转录组。这种时空转录组提供高分辨率的数字化原位基因表达谱，揭示了组织谱系的分子谱系，并定义了时间和空间中多能性状态的连续体。

Molecular architecture of lineage allocation and tissue organization in early mouse embryo

Prof. Jingdong HAN and her team report a spatially resolved transcriptome of cell populations at defined positions in the germ layers during development from pre- to late-gastrulation stages. This spatiotemporal transcriptome provides high-resolution digitized in situ gene-expression profiles, reveals the molecular genealogy of tissue lineages and defines the continuum of pluripotency states in time and space.



Molecular architecture of lineage allocation and tissue organization in early mouse embryo,Peng, G., Suo, S., Cui, G., Yu, F., Wang, R., Chen, J., Chen, S., Liu, Z., Chen, G., Qian, Y., et al,Nature 572, 528-532 (2019).

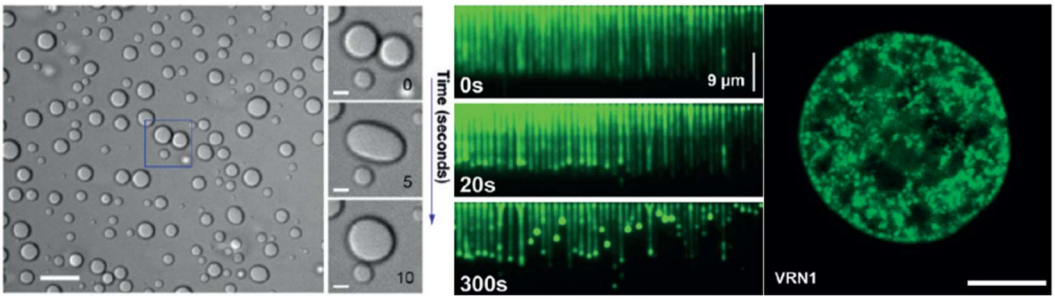
2. VRN1 通过相分离机制参与基因转录调控

齐志研究员与化学与分子工程学院来鲁华教授、生命科学学院瞿礼嘉教授等团队合作发现拟南芥转录抑制子 VRN1 可以与 DNA 形成液液相分离，且 VRN1 的两个 DNA 结合结构域和无序连接链对相分离都起到了重要作用。并通过 DNA 帘幕技术和体内实验进一步揭示了相变的分子机制，为理解基因转录调控提供了全新的视角。

DNA induced phase separation of VRN1

Vernalization 1 (VRN1) encodes a crucial transcriptional repressor involved in plant vernalization. This study revealed that both the B3 DNA binding domains and the charge pattern in the disordered linker are important for liquid-liquid phase separation(LLPS). Combined with DNA Curtains and cell imaging methods, Prof. Zhi QI team and collaborators further suggested that it may stabilize the vernalized state by repressing gene expression through LLPS providing a new

insight for transcription regulation.



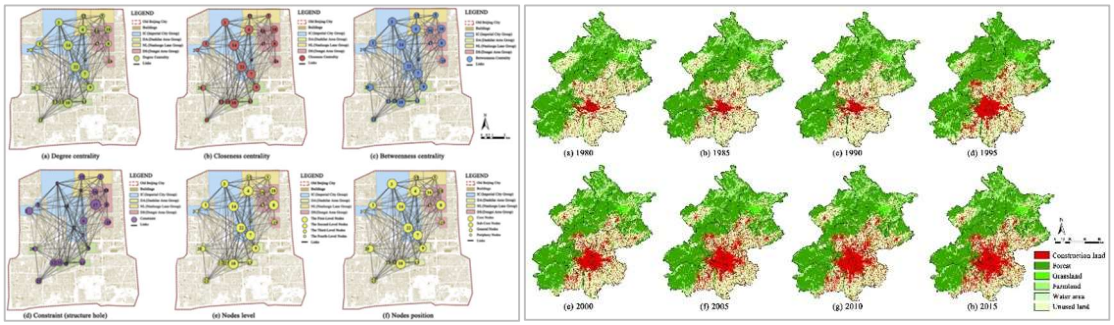
Mechanism of DNA-Induced Phase Separation for Transcriptional Repressor VRN1, H. Zhou, Z. Song, S. Zhong, L. Zuo, Z. Qi, L.-J. Qu*, L. Lai*, Angew. Chem. Int. Ed. 2019, 58, 4858 –4862.*

建筑与景观学院（College of Architecture and Landscape）

1．揭示城镇化过程中多尺度的地方性景观动态演化规律

地方性景观是城乡空间中人类活动与地理环境相互作用的产物，是人与自然“生命共同体”组成要素，是反映城乡发展的重要载体。汪芳团队的研究结果阐述城镇化过程中，建筑、地段、城镇等多尺度景观的自然-人文耦合关系，提出“节点-网络-背景”理论模型，将地方性景观作为一种整体现象进行系统性研究，并选取北京作为典型案例城市，从建筑遗产更新、旧城土地利用、城市能源消耗等角度，探讨地方性景观“环境影响-空间响应”的适应性机制，以推进土地集约化利用和城市可持续发展。

Reveal the dynamic evolution of multi-scale landscape with locality in the process of urbanization



Landscape with locality, as a significant part of the human-nature “living unity”, and an important embodiment of urban and rural development, is the result of the interaction between human activities and geographical environment in urban and rural space. Thus, the research results of Fang WANG’s team show the human-nature coupling relationship of multi-scale landscape (including buildings, blocks, cities, etc.) against the backdrop of urbanization, propose a “network–node–setting” theoretical model for city renewal and land use, and systematically assess landscape with locality as a whole. From the perspectives of architectural heritage renewal, land use in old cities and urban energy consumption, Beijing is

selected as a typical case to explore the adaptive mechanism of "environmental impact vs. spatial response" of landscape with locality, so as to promote the intensive land use and urban sustainable development.

Inheritance or variation? Spatial regeneration and acculturation via implantation of cultural and creative industries in Beijing's traditional compounds. Zeng, M.; Wang, F.; Xiang, S.N.; Lin, B.Y.; Gao, C.G.; Li, J.N.. Habitat International, https://doi.org/10.1016/j.habitatint.2019.102071 (2019)*

Isolated or integrated? Planning and management of urban renewal for historic areas in old Beijing city, based on the association network system. Liu, Z.; Wang, S.Y.; Wang, F.. Habitat International 93 102049 (2019)*

Predictions and driving factors of production-based CO2 emissions in Beijing, China. Liu, Z.; Wang, F.; Tang, Z.Y.*; Tang, J.T.. Sustainable Cities and Society 53 101909(2019)*

更多信息（For More Information）

北京大学科研部海外项目办公室,

办公电话: 86-10-62756820
电子邮箱: fsf@pku.edu.cn

Division for Overseas Projects,
Office of Scientific Research, Peking University
Tel: 86-10-62756820
Email: fsf@pku.edu.cn