北京大学科研亮点
（2023年度）

Peking University
Scientific Research Highlights 2023

北京大学科学研究部

2023 年 12 月

目 录

数学科学学院（School of Mathematical Sciences）

1．p 进制黎曼-希尔伯特问题研究

希尔伯特第 21 问题，也称黎曼-希尔伯特问题，是上世纪最重要的数学问题之一，推动产生了诸如复代数簇的 D 模理论、黎曼-希尔伯特对应等重大进展。鉴于这些理论所取得的巨大成功，数学家们希望在 p 进制情形也能建立相应的理论。**刘若川教授与合作者**建立了数学大师 Deligne 构造的复代数簇上的黎曼-希尔伯特对应的 p 进制版本，并对任意志村簇证明了 p 进黎曼-希尔伯特对应与 Deligne 的黎曼-希尔伯特对应的相容性。这一工作迅速引起了国际同行的广泛关注并引发了重要的后续进展，在最近 Pila-Shankar-Tsimerman 关于任意志村簇的 Andre-Oort 猜想的突破性工作中获得重大应用。相关成果发表在《美国数学会杂志》（基础数学四大顶尖杂志之一）。

p-adic Riemann-Hilbert correspondence

The 21st Hilbert problem, also known as the Riemann-Hilbert problem, was one of the most important mathematical problems of the last century. It spurred significant advancements such as the theory of D-modules for complex algebraic varieties and the Riemann-Hilbert correspondence. Given the great success of these theories, many mathematicians hope to establish corresponding theories in the p-adic setting. **Prof. Ruochuan LIU** and his collaborators established the p-adic version of Deligne's Riemann-Hilbert correspondence on complex algebraic varieties. They also proved the compatibility of the p-adic Riemann-Hilbert correspondence with Deligne's Riemann-Hilbert correspondence for any Shimura variety. This work has quickly attracted widespread attention from colleagues abroad and has led to significant subsequent developments. It has been applied crucially in the recent breakthrough work of Pila-Shankar-Tsimerman on the Andre-Oort conjecture for any Shimura variety. The result was published in 2023 in the Journal of the American Mathematical Society, one of the top four journals in mathematics.

Hansheng Diao, Kai-Wen Lan, Ruochuan Liu & Xinwen Zhu, Logarithmic Riemann–Hilbert correspondences for rigid varieties. Journal of the American Mathematical Society, 36(2), (2023), 483-562.

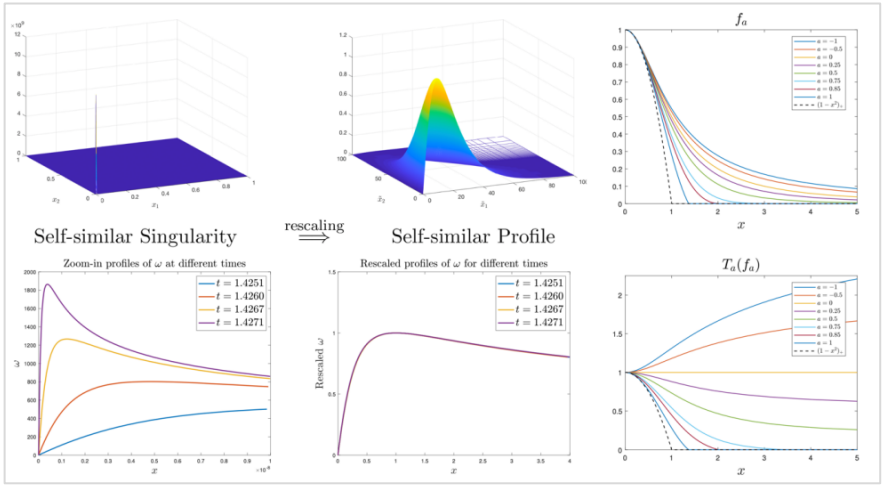
Kai-Wen Lan, Ruochuan Liu & Xinwen Zhu, De Rham comparison and Poincaré duality for rigid varieties. Peking Mathematical Journal, 6, (2023), 143 – 216.

2．一个不可压流体模型问题的自相似有限时间爆破解猜想证明

含有对流强度参数 a 的推广 Constantin-Lax-Majda（gCLM）方程是用于研究经典三维不可压缩 Euler 方程中涡度拉伸效应与对流效应之间对抗作用的重要一维模型。**黄得研究员团队**开创性地利用不动点方法，首次证明了 gCLM 模型对所有 $a \leq 1$ 都存在自相似有限时间爆破解，并给出了自相似解的精确刻画和分类，从而解决了该模型全参数范围下具有光滑轮廓的自相似爆破解存在性猜想。这一工作不仅为原三维 Euler 方程爆破问题的理论研究提供了新的理解和思路，同时也为相关流体方程自相似解的数值模拟计算提供了一种全新的不动点迭代算法。

Proving a conjecture on self-similar finite-time blowups of a fluid model

The a-parameterized family of the generalized Constantin-Lax-Majda (gCLM) equation is an important 1D model for studying the competition between vortex stretching and advection in the 3D incompressible Euler equations. For the first time, **De HUANG** and his research team proved a long standing conjecture on the gCLM model by establishing the existence of self-similar finite-time blowups with smooth profiles for the whole range of parameter $a \leq 1$ based on a novel fixed-point method, and they also obtained detailed characterizations and classification of these self-similar solutions. Their work not only provides new understanding and ideas for the theoretical study of the blowup problem of the original 3D Euler equations, but also provides a novel fixed-point iteration scheme for numerically computing self-similar solutions of related fluid equations.



De Huang, Xiang Qin, Xiuyuan Wang, and Dongyi Wei. Self-similar finite-time blowups with smooth profiles of the generalized Constantin-Lax-Majda model. To appear on Archive for Rational Mechanics and Analysis, 2023.

De Huang, Jiajun Tong, and Dongyi Wei. On self-similar finite-time blowups of the De Gregorio model on the real line. Communications in Mathematical Physics, 402, 2791-2829, 2023.

3．气候变化最优指纹方法的统计学评估

气候变化检测与归因的最优指纹法是全球气候变化研究和众多 IPCC 报告的基本方法。但近年来该方法的统计学基础受到一些学者的尖锐批判，为气候变化研究和 IPCC 结果的可靠性带来很大困扰和挑战。**陈松蹊教授团队**从统计学角度严格评判了该方法的科学性和实用性，严格给出最优指纹法成立的统计学条件，补充了现有方法缺失的条件，并突出强调建立更精确的气候模式模拟的重要性，同时也指出潜在的超高维分辨率所带来的高维数据挑战。该研究发表在气候变化方法学的顶级期刊 *Climate Dynamics* 上，回应了近年对最优指纹法的批判，也解决了气候变化研究领域对于该方法的担忧。

A statistical review on the optimal fingerprinting approach in climate change studies

The optimal fingerprinting method for climate change detection and attribution is the basic method of global climate change research and many IPCC reports. However, the statistical basis of this method has recently received severe criticism, which has brought great confusion and challenges to the reliability of climate change research and results that IPCC reported. Prof. Song Xi Chen's team strictly evaluates the science and practicability of the method from statistical perspectives, provides the statistical conditions for the optimality, and supplements other missing conditions in current method. Furthermore, they emphasize the importance of establishing more accurate climate models, and point out the potential challenges of high-dimensional data at high resolution. The paper is published in Climate Dynamics, a leading journal on climate change research. This study responds to criticism about optimal fingerprinting and settles concerns about this approach in climate change research.

Chen, H., Chen, S.X. & Mu, M. A statistical review on the optimal fingerprinting approach in climate change studies. Climate Dynamics (2023). https://doi.org/10.1007/s00382-023-06975-5.

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

4．有限商群全体几乎决定基本群

在三维流形的拓扑学研究中，近四十年的突出方法是 Thurston 几何化纲领。在这一视角下，基本群很大程度上决定着三维流形的拓扑，双曲几何又是其中最重要的流形类型。**刘毅教授**对于有限体积的双曲三维流形，独立、完整证明了基本群的准投射有限刚性。创造地结合运用了有限复叠的新兴构造方法和传统的 Nielsen 不动点指标理论，克服了核心技术困难，关键步骤是建立了定理条件下 Thurston 范数的不变性。有限体积的双曲三维流形的准投射有限刚性结果发表于 2023 年 *Invent. Math.*期刊(基础数学四大顶尖杂志之一)。这是目前三维拓扑领域内的突破性进展，是相关问题已知最好的一般性结果。

Finite-volume hyperbolic 3-manifolds are almost determined by their finite quotient groups

In the study of topology on 3-manifolds, a prominent method in the past four decades has been the Thurston Geometrization Conjecture. From this perspective, the fundamental group largely determines the topology of a 3-manifold, with hyperbolic geometry being the most important type of manifold. Prof. Yi LIU independently and completely proved the quasi-projective finitely rigid nature of the fundamental group for finite-volume hyperbolic 3- manifolds. He innovatively combined new construction methods of finite coverings with traditional Nielsen fixed-point index theory, overcoming core technical difficulties. A key step was establishing the invariance of the Thurston norm under theorem conditions. The results on the quasi-projective finite rigidity of finite-volume hyperbolic 3- manifolds were published in the 2023 in the journal of *Invent. Math*. This represents a breakthrough in the field of 3-dimensional topology, being the best general result about this problem known to date.

Yi Liu, Finite-volume hyperbolic 3-manifolds are almost determined by their finite quotient groups, Invent. Math. 231 (2023), 741--804.

5．从刘维尔共形场论到 SLE 的可积性

SLE 是一族描述二维统计物理模型连续极限的典范随机曲线，刘维尔共形场论(LCFT)是一种描述随机曲面的量子场论。**孙鑫教授**与合作者发展了 SLE 和 LCFT 的共形焊接框架并得到了 SLE 的可积性结果。该框架为研究渗流模型等重要二维统计物理模型的可积性提供了全新视角，为若干经典问题的解决奠定了基础。

Integrability of SLE via conformal welding of random surfaces

SLE is a canonical family of random curves describing the scaling limit of two-dimensional lattice models. Liouville conformal field theory (LCFT) is a quantum field theory that describes random surfaces. Prof. Xin Sun and collaborators developed the conformal welding framework for SLE and LCFT, based on which they obtained integrable results for SLE. This framework provides a new approach to study the integrability of important 2D lattice models such as percolation, and paves the way for the resolution of several classical problems.

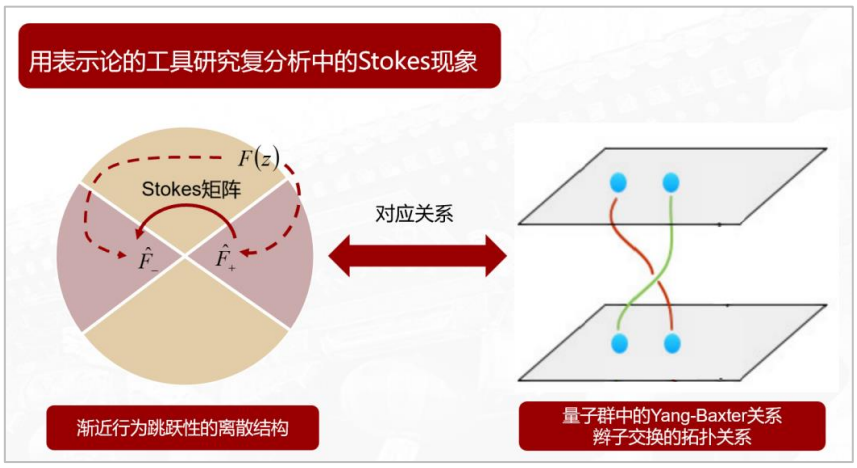
M. Ang, N. Holden, X. Sun. Integrability of SLE via conformal welding of random surfaces. Communications on Pure and Applied Mathematics. Online. 2023.

6．Stokes 现象与量子群的关系

Stokes 现象描述了微分方程的解在奇点处渐近行为的跳跃性。近三十年来该现象与数学和物理的诸多领域产生了深刻的联系，成为国际上研究的热点。徐晓濛与合作者首次建立了该现象与量子群表示理论的关系。这项工作为研究 Stokes 现象所蕴含的复杂超越性数据提供了代数组合工具和新的研究思路。以此为基础，徐晓濛研究组解决了该领域一系列重要的分析问题。

Stokes phenomena, Poisson–Lie groups and quantum groups

Stokes phenomenon describes the jump of the asymptotics of complex functions at singularities. It has played significant roles in many subjects of mathematics and physics. With his collaborator, Xiaomeng Xu discovers a deep connection between Stokes phenomenon and the representation theory of quantum groups. This work makes it possible to study the highly transcendental phenomenon via an algebraic approach. Based on the work, Xiaomeng Xu team solves some important problems in the field.



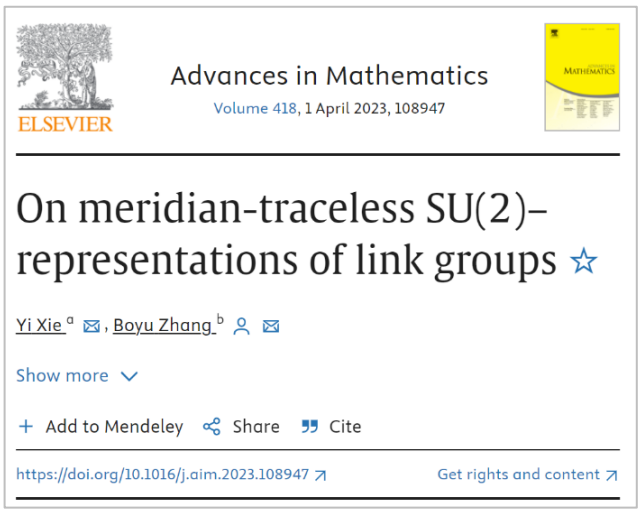
Valerio Toledano Laredo and Xiaomeng Xu, Stokes phenomena, Poisson – Lie groups and quantum groups, Advances in Mathematics, Volume 429, 15 September 2023, 109189.

7．三维空间中链环基本群的不可约酉表示的存在性

三维流形基本群的表示是三维拓扑中的一类核心问题。**谢羿**助理教授及其合作者证明了任意非 Hopf 链环补的基本群都存在不可约特殊酉表示，同时在这一结果基础上联系了几何拓扑与计算复杂度这两个不同领域，证明了 Hopf 链环的探测问题是反 NP 问题。这些结果为更一般的三维流形基本群表示以及几何拓扑中的计算复杂度问题的研究提供了新的理论基础。

Irreducible SU(2) representations of the fundamental groups of link complements

Yi Xie and his collaborator proved that the fundamental group of a link complements admits an irreducible meridian-traceless representation in SU(2) if and only if the link is not the unknot, the Hopf link, or a connected sum of Hopf links. As a corollary, the link group admits an irreducible representation in SU(2) if and only if L is neither the unknot nor the Hopf link.



Xie, Yi; Zhang, Boyu. On meridian-traceless SU(2)-representations of link groups. Adv. Math.418(2023), Paper No. 108947, 48 pp.

物理学院（School of Physics）

8．多芯片高维量子纠缠网络成功构建

量子网络是未来量子科技走向应用的重要基础支撑。**王剑威研究员和龚旗煌院士团队与合作者**实现了集成光量子芯片间的高维量子纠缠网络。团队发展了硅基光量子芯片晶圆级制造技术，提出一种高维量子纠缠自修复方法，为进一步构建大规模可实用化量子网络开辟了新路径。

The demonstration of multichip multidimensional quantum entanglement networks

Quantum networks are the foundation for the future implementation of quantum technology. **Prof. Jianwei WANG, Qihuang GONG** research team and collaborators realize the multidimensional quantum entanglement networks between multiple integrated photonic chips. They have developed wafer-scale fabrication technologies for silicon quantum photonic chips and proposed an entanglement retrieving method, which opens up a new path for further construction of large-scale practical quantum networks.

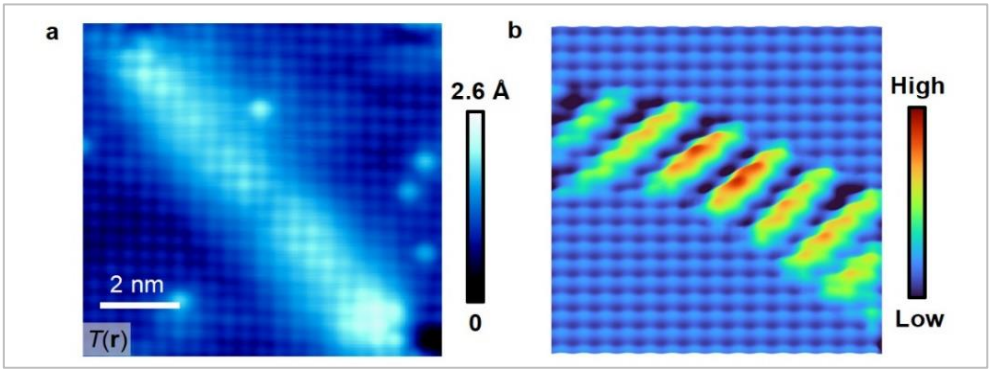
Multichip multidimensional quantum networks with entanglement retrievability. Y. Zheng, C. Zhai, D. Liu, J. Mao, X. Chen, T. Dai, J. Huang, J. Bao, Z. Fu, Y. Tong, X. Zhou, Y. Yang, B. Tang, Z. Li, Y. Li, Q. Gong, H. K. Tsang, D. Dai, J. Wang. Science 381, 221-226 (2023).

9．在二维铁基高温超导体中发现配对密度波态

非常规高温超导和低维超导是当代凝聚态物理的研究前沿。在研究铜基高温超导体的过程中，一种由非零动量的库珀对凝聚形成的新型超导态——配对密度波态被理论预测以低维的形式存在于非常规超导体中。然而，在铁基高温超导体以及低维超导体中，配对密度波态一直未得到实验的证实。通过超高真空分子束外延以及原位低温扫描隧道显微镜和扫描隧道谱技术，**王健教授研究组**与合作者在单层铁基高温超导薄膜中首次发现了本征配对密度波，为研究非常规超导体中的配对密度波机理、非常规高温超导电性以及拓扑电子态提供了一个新的研究平台。

Discovery of pair density wave state in a two-dimensional high-Tc iron-based superconductor

Unconventional high-temperature (high-T_c) superconductors and low-dimensional superconductors are research frontiers in condensed matter physics. Previous studies of high-T_c cuprate superconductors proposed that an extraordinary superconducting state, which is formed by finite-momentum Cooper pairs and referred to as the pair density wave (PDW), can exist in unconventional high-T_c superconductors as a low-dimensional stripe order. However, the existence of PDW state in iron-based superconductors and low-dimensional superconductors has never been experimentally detected. By using molecular beam epitaxy and scanning tunneling microscopy/spectroscopy techniques, **Prof. Jian Wang's group** and collaborators discovered the primary pair density wave state in a two-dimensional iron-based high-T_c superconductor, which provides a new quantum material platform to study the PDW state and its interplay with the topological electronic states and unconventional high-T_c superconductivity.



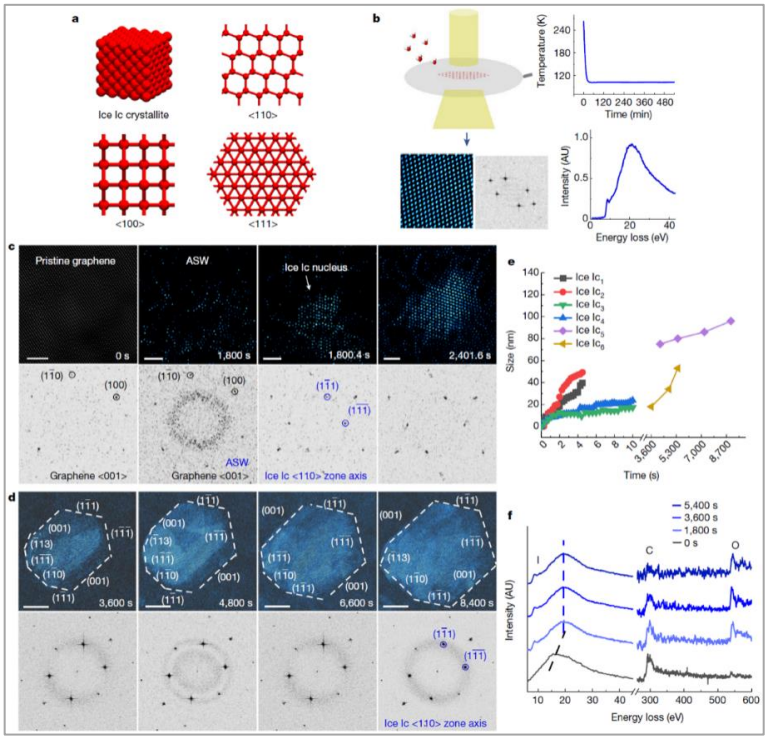
Pair density wave state in a monolayer high-T_c iron-based superconductor. Y. Liu, T. Wei, G. He, Y. Zhang, Z. Wang, J. Wang. Nature 618, 934-939 (2023).

10．揭示立方冰生长的微观过程

立方冰的形核及生长过程是过去几十年中一个极具争议的科学问题。**王恩哥院士和陈基研究组**与合作者对高纯单晶立方冰的生长机制进行了深入实验和理论探索，揭示了立方冰生长的微观过程。该工作对于我们理解自然界中冰的成核机制和立方冰-六角冰转变等过程都有重要意义。

Revealing the microscopic process of cubic ice growth

The nucleation and growth of cubic ice has been a highly controversial scientific topic in the past few decades. **Prof. Enge WANG, Chen JI**'s research group and collaborators conducted in-depth experiments and theoretical explorations on the growth mechanism of high-purity single-crystal cubic ice, revealing the microscopic process of cubic ice growth. This work is of great significance for our understanding of the nucleation mechanism of ice and the transition between cubic ice and hexagonal ice in nature.



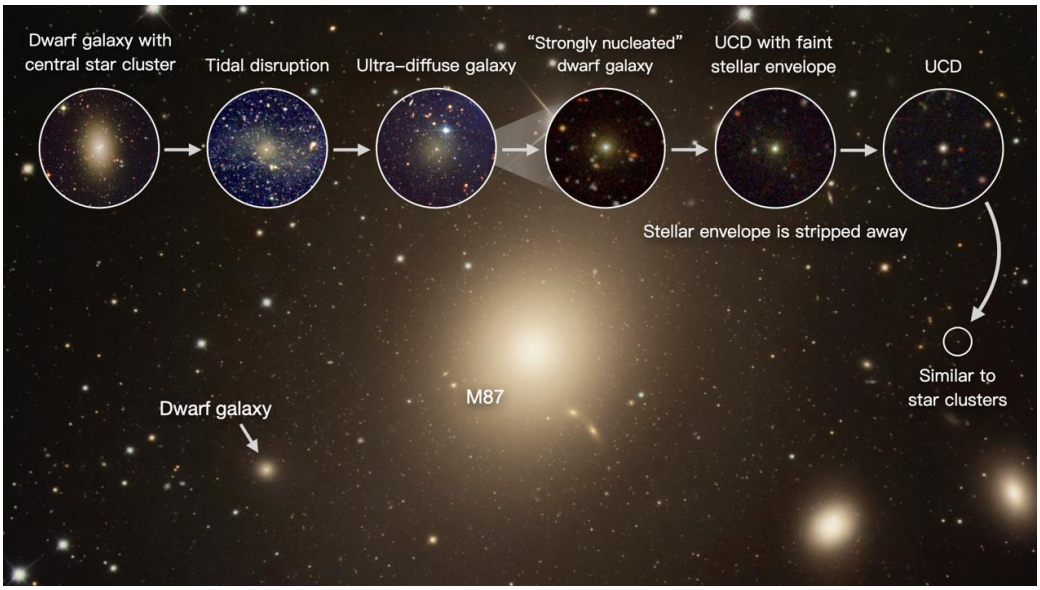
Tracking cubic ice at molecular resolution. Xudan Huang, Lifen Wang, Keyang Liu, Lei Liao Huacong Sun, Jianlin Wang, Xuezeng Tian, Zhi Xu, Wenlong Wang, Lei Liu, Ying Jiang4,6, Ji Chen, Enge Wang & Xuedong Bai, Nature 617, 86-91 (2023).

11．观测揭示超致密矮星系的形成过程

利用多台国际大型望远镜的多年细致观测和搜寻，研究团队在室女星系团里发现了上百个由于被潮汐剥离，正从普通星系向超致密矮星系演化的过渡天体，首次完整呈现了宇宙中一类性质极端的星系——超致密矮星系的形成演化过程。这些星系演化的“化石遗迹”填补了长期以来星系和星团间的空白区域。

Revealing the Formation of Dense Dwarf Galaxy ‘Fossils’

With deep and high-resolution imaging, an international team of astronomers have captured the eroding remains of more than 100 galaxies in an elusive state of transformation in the Virgo Cluster. These findings confirm that some of the densest galaxies in the Universe, dubbed “ultra-compact dwarf galaxies” (UCDs) are likely the fossil remains of normal nucleated dwarf galaxies that have been stripped of their outer layers of stars by strong tidal force. These objects fill long-observed gap between dwarf galaxies and star clusters.



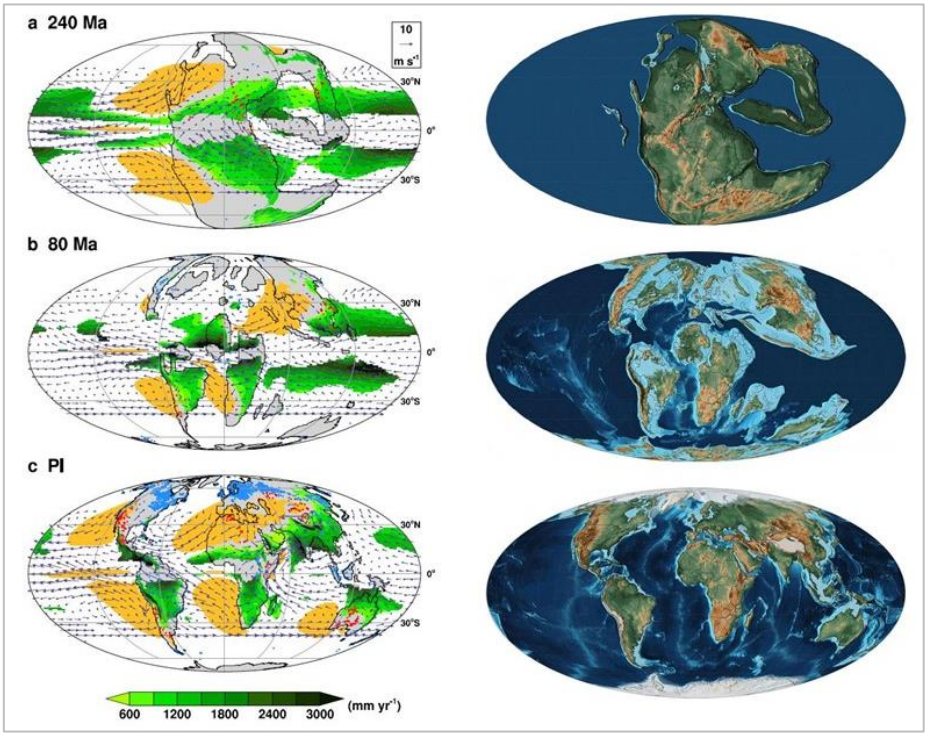
An evolutionary continuum from nucleated dwarf galaxies to star clusters. Wang, K., Peng, E.W., Liu, C, Mihos, J.C., Côté, P., Ferrarese, L., Taylor, M.A., Blakeslee, J.P., Cuillandre, J.C., Duc P.A., Guhathakurta, P., Gwyn, S, Ko, Y., Lançon, A., Lim, S., MacArthur, L.A., Puzia, T., Roediger, J., Sales, L.V., Sánchez-Janssen, R., Spengler C., Toloba E., Zhang H. & Zhu, M. Nature 623, 296–300 (2023).

12．显生宙气候和全球季风系统演变模拟研究

胡永云教授团队对显生宙气候演化开展了系统模拟研究，阐述了季风系统的演变规律，提出了板块运动对热带辐合带位置的驱动作用，证实了早侏罗纪极热事件期间存在超强台风，建立了煤和蒸发岩等外生矿床与温度降水的定量关系。

Simulating climate and global monsoon evolution of the Phanerozoic

Prof. Yongyun Hu and his team have done systematic climate simulations of the Phanerozoic. They addressed that global land-monsoon area and precipitation intensity are highly anti-correlated, and that both are determined by continental area, location, and fragmentation. They demonstrated how the inter-tropical convergence zone is driven by continental configurations. Combining simulations and geological records, they confirmed there existed super-tropical cyclones during the hyper-hot event of the early Jurassic. They also established quantitative relationships of coals and evaporites with temperature and precipitation.



Left panels: global monsoon distribution for three typical times. Green shading: monsoon regions, color scale is annual mean precipitation. Yellow shading indicates dry regions. Right panels: land-sea distributions of the three typical times. Ma: million years ago.

Emergence of the modern global monsoon from the Pangea Megamonsoon set by paleogeography.Hu, Y., X. Li, W. R. Boos, J. Guo, J. Lan, Q. Lin, J. Han, J. Zhang, X. Bao, S. Yuan, Q. Wei, Y. Liu, J. Yang, J. Nie, and Z. Guo, Nature Geoscience 16 1041-1046(2023).

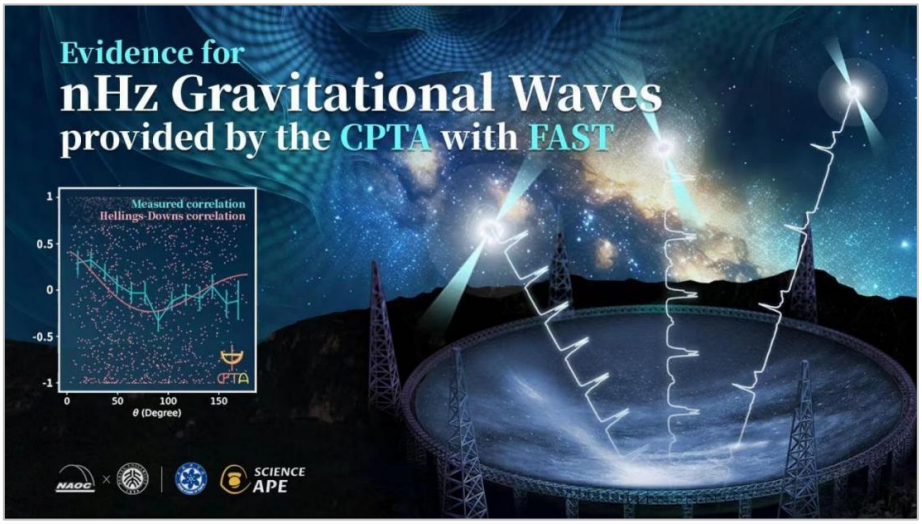
科维理天文与天体物理研究所（Kavli Institute for Astronomy and Astrophysics）

13．深度参与纳赫兹引力波搜寻研究并取得重大突破

中国脉冲星测时阵列（CPTA）研究团队利用中国天眼——500 米口径球面射电望远镜（FAST），探测到纳赫兹引力波存在的关键性证据，表明我国纳赫兹引力波研究与国际同步达到领先水平。**李柯伽长聘副教授团队**深度参与了该项工作。

Found Key Evidence for Existence of Nanohertz Gravitational Waves

A group of Chinese scientists has recently found key evidence for the existence of nanohertz gravitational waves, marking a new era in nanohertz gravitational wave research. The research was based on pulsar timing observations carried out with the Five-hundred-meter Aperture Spherical Telescope (FAST), and was conducted by the Chinese Pulsar Timing Array (CPTA) collaboration. **Prof. Kejia Lee** and his research team played vital roles in the collaboration.



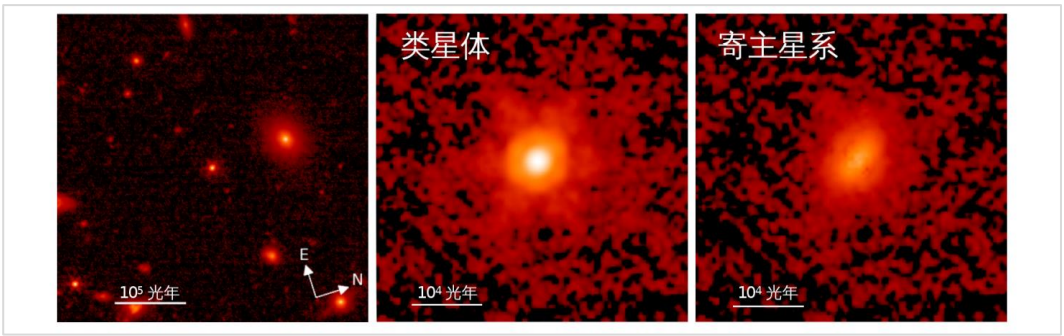
Searching for the Nano-Hertz Stochastic Gravitational Wave Background with the Chinese Pulsar Timing Array Data Release I, Xu H., Chen S.Y., Guo Y.J., Jiang J.C., Wang B.J., Xu J.W., Xue Z.H., Caballero R..N, Yuan J.P., Xu Y.H., Wang J.B., Hao L.F., Luo J.T., Lee K.J., Han J.L. et al. Research in Astronomy and Astrophysics, 2023, 23, 075024.

14．探测到宇宙诞生初期类星体的寄主星系

詹姆斯·韦布空间望远镜最新观测数据首次揭示宇宙大爆炸早期两颗快速增长的超大质量黑洞（类星体）所在寄主星系的星光。**Masafusa Onoue（尾上匡房）博士后研究员**与合作者在《自然》杂志上发表新成果，表明这些超大黑洞的质量接近太阳的十亿倍，而寄主星系的质量几乎是后者的上百倍。该质量关系与来自临近星系的观测结果一致。

Probe the Relationship Between the Black Holes and the Host Galaxies

New images from the James Webb Space Telescope (JWST) have revealed, for the first time, starlight from two massive galaxies hosting actively growing black holes – quasars – seen less than a billion years after the Big Bang. The black holes have masses close to a billion times that of the Sun, and the host galaxy masses are almost one hundred times larger, a ratio similar to what is found in the more recent universe. A powerful combination of the wide-field survey of the Subaru Telescope and the JWST has paved a new path to study the distant universe, reports a new study in *Nature*.



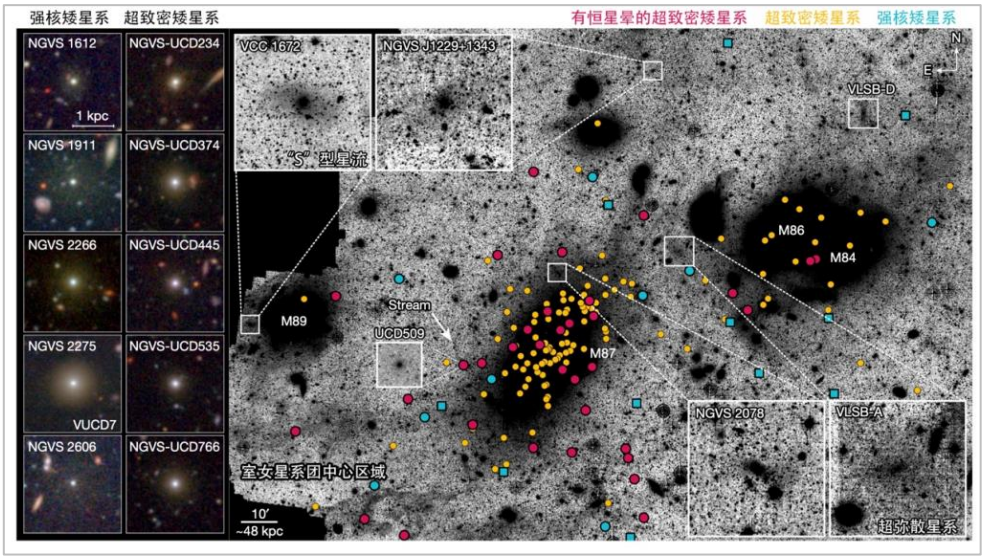
Detection of stellar light from quasar host galaxies at z > 6, Ding X.H., Onoue M., Silverman J.D., Matsuoka Y., Izumi T. et al. Nature, 2023, 621,51-55.

15．揭示超致密矮星系的演化起源

由中国天文学家主导，来自全球近 20 个研究机构的科研人员组成的国际团队，使用哈勃空间望远镜（HST）、加拿大-法国-夏威夷望远镜（CFHT）和北双子座望远镜（Gemini North）等的观测数据，发现了矮星系在星系团致密环境中被瓦解剥离，逐渐演化为超致密矮星系的完整过程，揭示了困扰天文学家许久的超致密矮星系起源之谜。

Reveal the Formation of Dense Dwarf Galaxy ‘Fossils’

An international team of astronomers using the Canada-France-Hawai‘i Telescope (CFHT), Gemini North telescope (Gemini North), Hubble Space Telescope (HST), and Case Western Reserve University's Burrell Schmidt Telescope, have captured the eroding remains of more than 100 galaxies in an elusive state of transformation. These findings confirm that some of the densest galaxies in the Universe, dubbed “ultra-compact dwarfs” (UCDs) are likely the fossil remains of normal dwarf galaxies that have been stripped of their outer layers.



An evolutionary continuum from nucleated dwarf galaxies to star clusters, Ding X., Onoue M., Silverman J. D., Matsuoka Y., Izumi T., Strauss M. A., Jahnke K., Phillips C. L., Li J.el al. Nature,2023, 623, 296 –300.

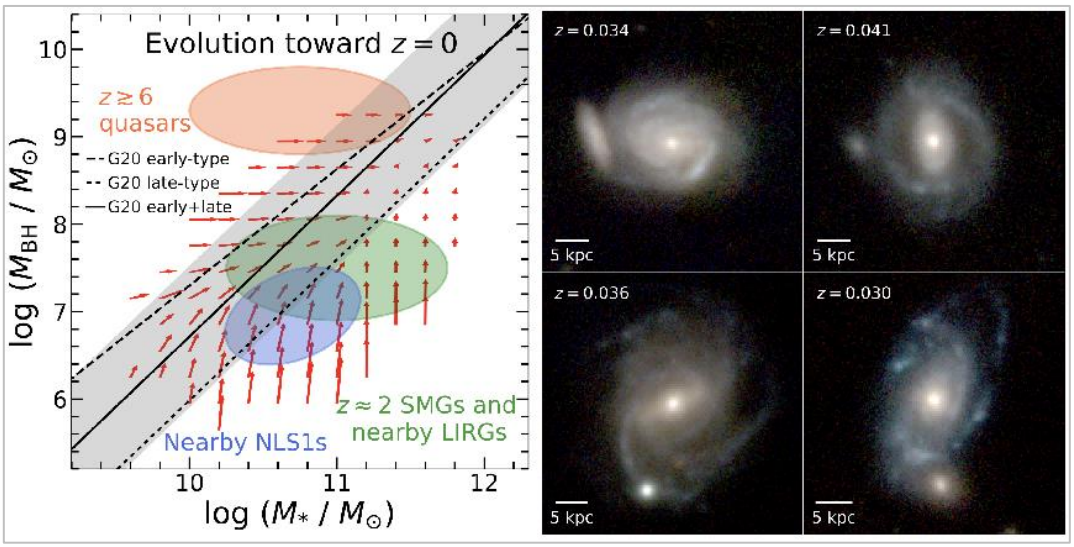
16．揭示超大质量黑洞及其宿主星系的演化路径

借助 Pan-STARRS13PI Steradian 巡天的数据，**庄明阳博士和何子山教授团队**对将近 11500 个红移≤0.35 的 I 型活动星系核宿主星系的结构和测光性质进

行了测量，由此深入研究了近邻宇宙中黑洞质量与宿主星系物理性质之间的关系，为研究超大质量黑洞及其宿主星系的协同演化提供了重要的新见解。

Sheds Light on Evolutionary Paths of Supermassive Black Holes and Their Host Galaxies

A new paper published in Nature Astronomy provides critical new insights on the co-evolution of supermassive black holes and their host galaxies. The research derived structural and photometric properties of host galaxies of nearly 11,500 redshift ≤ 0.35 unobscured active galactic nuclei (AGNs) using data from Pan-STARRS1 3PI Steradian Survey to explore the connections between black hole mass and the properties of host galaxies in the nearby Universe.



Evolutionary paths of active galactic nuclei and their host galaxies，Zhuang M.-Y, Ho L.C., Nature Astronomy，7，1376–1389.

17．何子山教授当选美国艺术与科学院院士

何子山教授是国际知名的天体物理学家，他在超大质量黑洞和星系演化方面的研究涵盖了广泛不同但相互关联的领域，使用了从无线电到 X 射线能量的所有观测技术。何子山教授于 2023 年当选为美国艺术与科学院（AAAS）院士。美国艺术与科学院成立于 1780 年，旨在表彰成就卓越的杰出学者，汇集人类各个领域的领导者来检验新思想，解决对国家和世界具有重要意义的问题。

Prof. Luis C. Ho Elected as a Member of AAAS

Prof. Luis C. Ho, Director of the Kavli Institute for Astronomy and Astrophysics (KIAA) and Chair Professor of Peking University, has been elected as a new member of the American Academy of Arts and Sciences (AAAS). The AAAS honors excellence and convenes leaders from every field to examine new ideas, address issues of importance to the world, and work together to, as expressed in its charter, cultivate every art and science which may tend to advance the interest, honor, dignity, and happiness of a free, independent, and virtuous people." Prof. Ho is an internationally renowned astrophysicist, whose research on supermassive black holes and galaxy evolution covers a wide range of different but interrelated areas, using all observational techniques spanning from radio to X-ray energies.

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

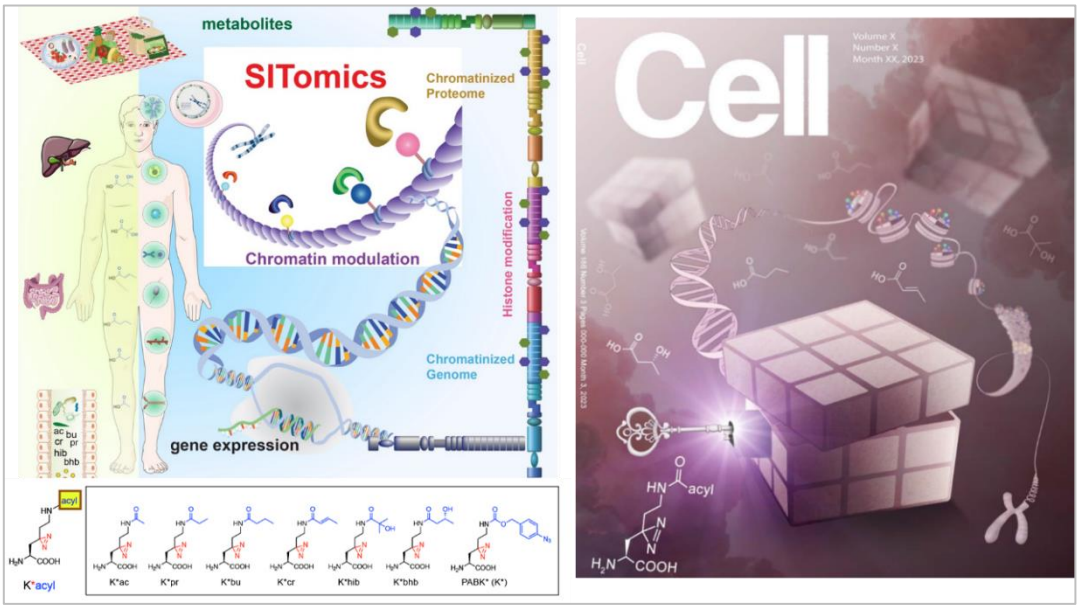
18．活细胞中染色质化学修饰的编码表达与关联解析

来自环境的代谢物会通过细胞内染色质的化学修饰实现基因转录调控，但作为表观遗传调控的重要分子基础，人们对很多化学修饰，尤其是位点特异的动态修饰对基因表达调控的影响尚不清楚，亟需对这些多层次的表观遗传信息加以解析和关联。**陈鹏教授团队和生命科学学院季雄课题组**发展了在活细胞内同步解析染色质相互作用蛋白质组和基因组的单位点-多组学技术-SiTomics，实现了染色质水平的组蛋白动态修饰及相互作用系统解析。基于所开发的双功能光交联探针，揭示了受染色质酰化修饰调控的蛋白质组-基因组 "信息关联"，发现了代谢与转录调控之间的新模式。SiTomics 技术为深入开展蛋白质动态修饰的机制研究、开发相应的化学干预策略提供了强大的平台。

Establishing the linkages of chromatin mark-defined proteome and genome in living cells

A generalizable strategy with programmable site-specificity for in situ profiling of histone modifications on unperturbed chromatin remains highly desirable but challenging. We herein developed a Single-site-resolved multi-omics (SiTomics) strategy for systematic mapping of dynamic modifications, and subsequent profiling of chromatinized proteome and genome defined by specific chromatin marks in living cells. Relying on the orthogonality and programmability of the genetic code expansion strategy, SiTomics fulfills the unmet need for in situ, programmable, multi-dimensional probing of site-specific histone lysine acylations on physiological chromatin, and established direct linkages for chromatin acylation-defined proteome, genome and functions. SiTomics is

widely applicable for multi-omics profiling and functional dissection of modifications beyond acylations and proteins beyond histones.



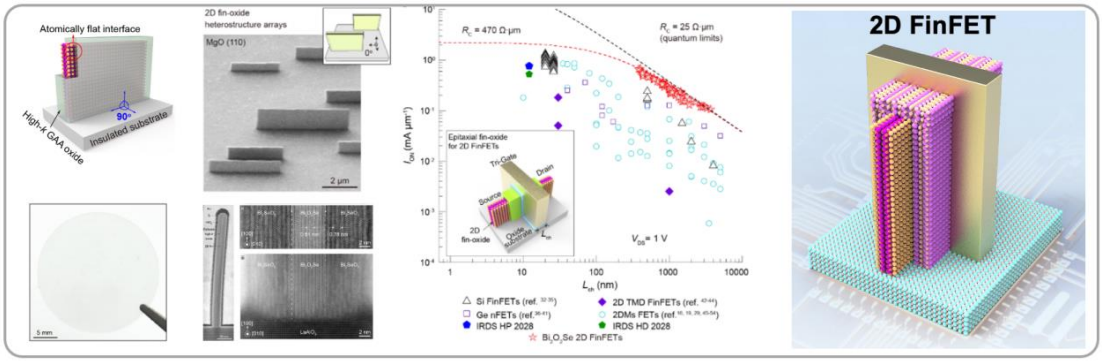
Qin F, Li B, Wang H, Ma S, Li J, Liu S, Kong L, Zheng H, Zhu R, Han Y, Yang M, Li K, Ji X*, Chen P*, "Linking chromatin acylation mark-defined proteome and genome in living cells", Cell, 2023, 186, 1066-1085.*

19．创制了外延高κ栅介质集成型二维鳍式晶体管

彭海琳教授团队实现了世界首例二维半导体鳍片/高 κ 栅氧化物异质结阵列的外延生长及其三维架构的异质集成，并研制了高性能二维鳍式场效应晶体管（2D FinFET）。该原创性工作突破了后摩尔时代高速低功耗芯片的二维半导体/高 κ 栅介质精准合成与新架构三维异质集成瓶颈，为开发未来先进芯片技术带来新机遇。

2D fin field-effect transistors integrated with epitaxial high-κ gate oxide

Prof. Hailin PENG and his research team report the epitaxial synthesis of vertically aligned arrays of 2D fin-oxide heterostructures, a new class of 3D architecture in which high-mobility 2D semiconductor fin Bi2O2Se and single-crystal high-k gate oxide Bi2SeO5 are epitaxially integrated. They achieved a remarkable breakthrough in the design of scaled nanoelectronics by creating a 3D vertical fin field-effect transistor (finFET) architecture based on 2D Bi2O2Se/Bi2SeO5.



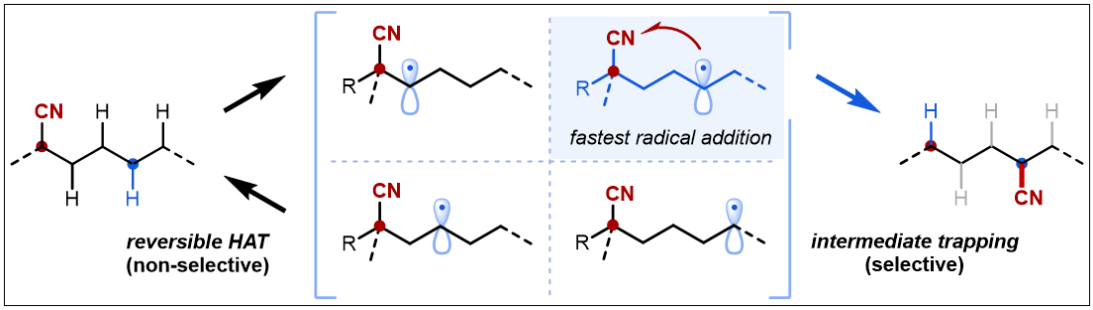
Congwei Tan#, Mengshi Yu#, Junchuan Tang#, Xiaoyin Gao#, Yuling Yin, Yichi Zhang, Jingyue Wang, Xinyu Gao, Congcong Zhang, Xuehan Zhou, Liming Zheng, Hongtao Liu, Kaili Jiang, Feng Ding, Hailin Peng. 2D fin field-effect transistors integrated with epitaxial high-k gate oxide. Nature 2023, 616, 66-72.*

20. “随机采样，单点转化”策略实现碳氢键-官能团位置互换

惰性碳氢键的选择性转化被誉为合成化学的圣杯。**许言研究员团队**基于对自由基介导惰性碳氢键转化中新方法、新机制的探索，提出了“随机切断碳氢键，但只挑选特定中间体进行转化”的碳氢键采样策略。通过将非选择性的可逆氢原子攫取与选择性的分子内中间体捕获进行联动，发展了将脂肪腈中氰基和 δ 碳氢键精准交换位置的新颖反应。这一新机理范式在碳氢键转化领域具有广阔的应用前景，为开发具实用价值的碳氢键转化带来了新的助力。

Reversible C–H Sampling for Direct Functional Group Translocation

The selective elaboration of C–H bonds holds significant importance in synthetic chemistry. **Prof. Yan XU** has recently pioneered an innovative strategy to precisely control site-selectivity in radical-mediated C–H transformations. This strategy combines multi-positioned hydrogen atom abstraction with site-selective intramolecular radical trapping, enabling a novel and valuable C–H transformation: the direct "position swapping" between cyano groups and unactivated δ C–H bonds.



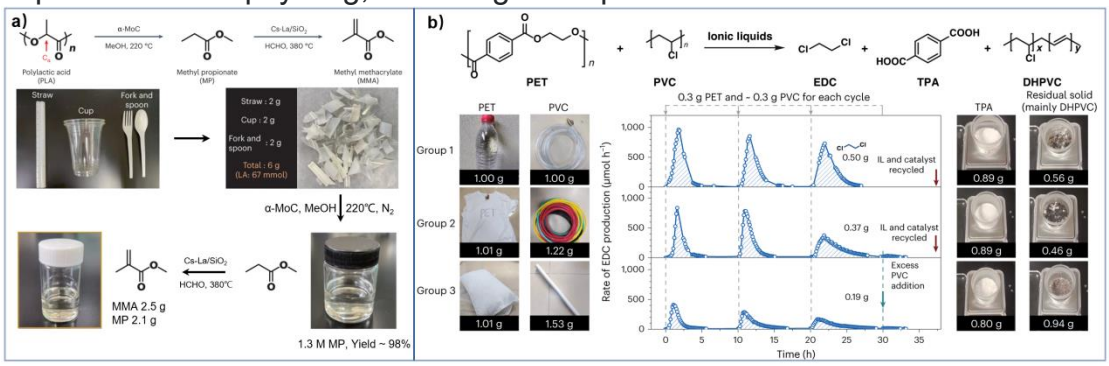
Chen K, Zeng Q, Xie L, Xue Z, Wang J, Xu Y. Functional-group translocation of cyano groups by reversible C–H sampling. Nature, 2023, 620, 1007-12.*

21．聚酯类废塑料升级回收的新反应路线设计

塑料的广泛使用和大规模遗弃造成了严重的环境污染问题。**马丁教授课题组**设计并实现了多条废塑料升级转化的新反应路线，如从聚乳酸塑料制备重要化工品甲基丙烯酸甲酯，从含氯混合塑料制备对苯二甲酸和二氯乙烷；并受邀为 Nature Sustainability 撰写观点文章“Transforming end-of-life plastics for a better world”，阐述废塑料转化中的重要科学问题与挑战，引起了广泛关注。

New Reaction Pathways for Upcycling Polyester Waste Plastics

Professor Ding MA's team has successfully designed and implemented novel reaction pathways for upcycling various waste plastics. They have developed a route to produce the important chemical methyl methacrylate from polylactic acid plastics, and synthesized phthalic acid and dichloroethane from chlorinated mixed plastics. Professor Ma was also invited to contribute a world view article, "Transforming end-of-life plastics for a better world," for Nature Sustainability, where he discusses the crucial scientific issues and challenges in plastic waste upcycling, attracting widespread attention.



Valorization of waste biodegradable polyester for methyl methacrylate production. B. Sun, J. Zhang, M. Wang, S. Yu, Y. Xu, S. Tian, Z. Gao, D. Xiao, G. Liu, W. Zhou, M. Wang, D. Ma, Nature Sustainability 6, 712-719 (2023). Co-upcycling of polyvinyl chloride and polyesters. R. Cao, M. Zhang, Y. Jiao, Y. Li, B. Sun, D. Xiao, M. Wang, D. Ma, Nature Sustainability https://doi.org/10.1038/s41893-023-01234-1, (2023). D. Ma, Transforming end-of-life plastics for a better world. Nature Sustainability 6, 1142-1143 (2023).

生命科学学院 (School of Life Sciences)

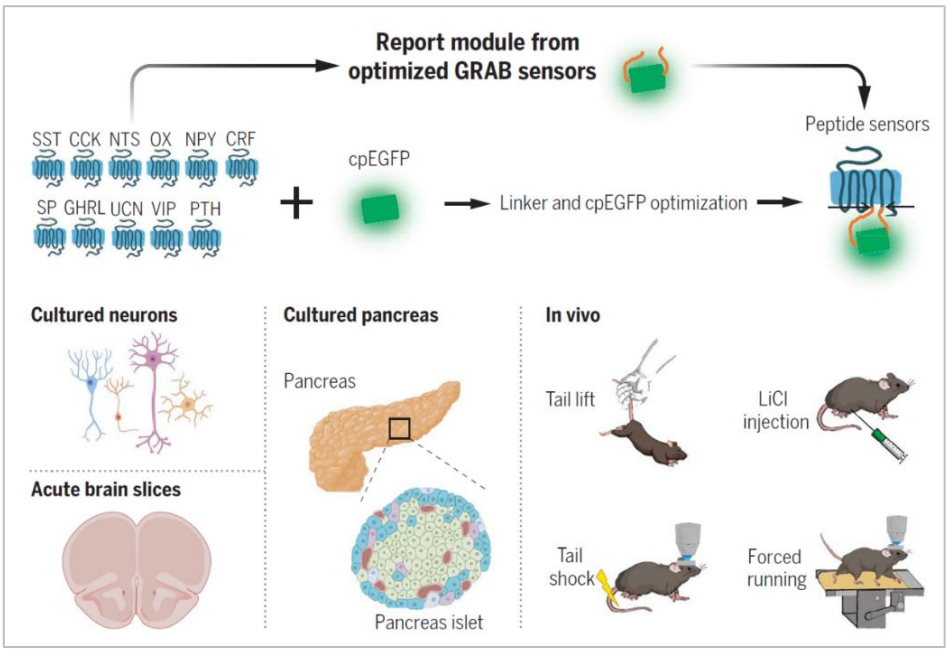
22．通用型嫁接策略开发神经肽荧光探针工具包

人体中有上百种神经肽，它们在调节生理和病理过程中发挥着重要作用，如何在活体中快速灵敏地检测神经肽是领域内的技术瓶颈。**李毓龙教授团队**开发了一种通用型的神经肽探针嫁接策略，成功地构建了 7 种基于 G 蛋白偶联受体激活原理（GRAB）的神经肽荧光探针，实现了对特定神经肽生物活性的实时、在体地

高效检测。该工作为研究神经肽在生理和病理状态下的释放、调控和功能提供了重要工具，为神经科学研究提供了重要的底层技术，填补国际空白。

Monitoring neuropeptide signals in vivo

To understand the functions of crucial neuropeptide signaling in vivo, it is essential to monitor their dynamics with high sensitivity, specificity, and spatiotemporal resolution. **Prof. Yulong LI**'s group from the School of Life Sciences has invented a generic grafting strategy and developed GPCR-activation-based (GRAB) fluorescent sensors for 7 neuropeptides. These sensors offer valuable insights into the dynamics of neuropeptides in both central and peripheral nervous systems. Importantly, the grafting strategy is scalable, holding great potential for covering a diverse range of neuropeptides, which offer opportunities to investigate the release, regulation, and role of neuropeptides in both physiological and pathological states.



1. Wang, H.; Qian, T.; Zhao, Y.; Zhuo, Y.; Wu, C.; Osakada, T.; Chen, P.; Chen, Z.; Ren, H.; Yan, Y.; Geng, L.; Fu, S.; Mei, L.; Li, G.; Wu, L.; Jiang, Y.; Qian, W.; Zhang, L.; Peng, W.; Xu, M.; Hu, J.; Jiang, M.; Chen, L.; Tang, C.; Zhu, Y.; Lin, D.; Zhou, J.-N.; Li, Y. A Tool Kit of Highly Selective and Sensitive Genetically Encoded Neuropeptide Sensors. Science ***2023****, 382 (6672), eabq8173.*

2. Qian, T.; Wang, H.; Wang, P.; Geng, L.; Mei, L.; Osakada, T.; Wang, L.; Tang, Y.; Kania, A.; Grinevich, V.; Stoop, R.; Lin, D.; Luo, M.; Li, Y. A Genetically Encoded Sensor Measures Temporal Oxytocin Release from Different Neuronal Compartments. Nat. Biotechnol. ***2023****, 41 (7), 944–957.*

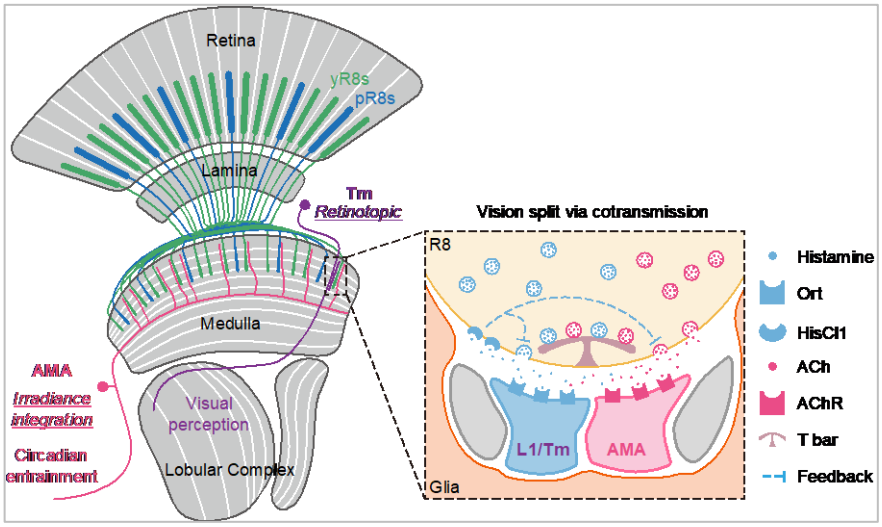
23．递质共传递分离视觉信号的神经机制

视觉作为机体最重要的感觉之一，其主要功能是分辨图像，但与图像生成并无直接关联的非图像视觉功能也调节了动物的生理和行为（如昼夜节律的调节）。

然而，同一感光通路如何产生并分离出这两类不兼容的不同视觉信号的神经机制还不清楚。**罗冬根研究员团队**在果蝇大脑中发展了国际领先的多电极膜片钳电生理记录技术，用此发现了果蝇复眼的一个感光细胞可通过同时释放两种不同递质来分离图像视觉和调节昼夜节律的非图像视觉信号的突触和环路机制。这种在视觉信号发生的最初环节（一个感光细胞释放两种递质）来分离图像和非图像视觉信号的方式，是一种全新的视觉机制，极大促进了领域内对视觉形成的理解，并为研究哺乳动物大脑中广泛存在的“递质共传递”现象提供新的范式和思路。

A single photoreceptor splits perception and entrainment by cotransmission

Vision is a vital sense for many species. How the image-forming pathway functionally segregates the contrast and irradiance visual signals remains unknown. Using the advanced multi-electrode patch-clamp recordings techniques, **Prof. Dong-Gen LUO**'s team discovered that a type of light-sensitive cell in fruit flies transmits two chemical messengers in response to the same light signal. These two molecules act on distinct neurons that have different functions: one type creates an image and the other synchronizes biological rhythms with the day–night cycle. This work expands our knowledge of sensory and circadian biology and also sheds light on the understanding of co-transmission in the nervous system.



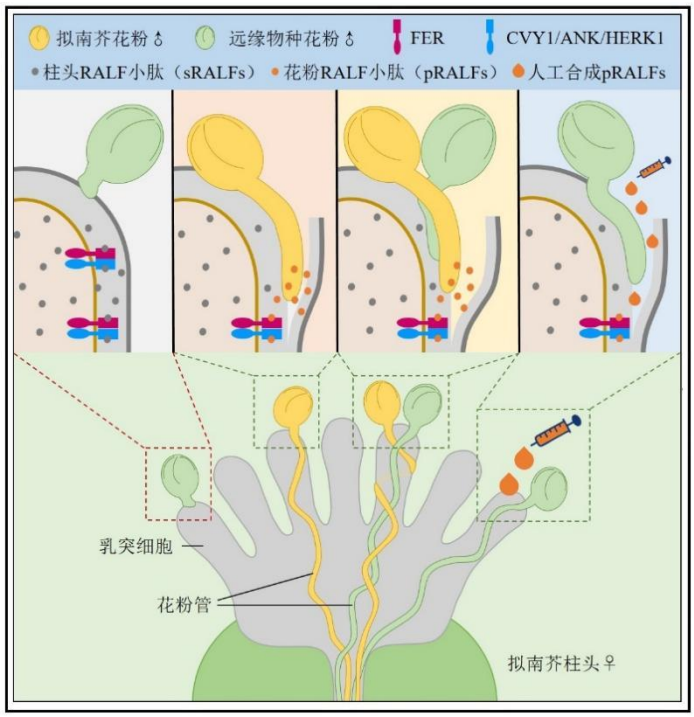
Xiao N, Xu S, Li ZK, Tang M, Mao R, Yang T, Ma SX, Wang PH, Li MT, Sunilkumar A, Rouyer F, Cao LH, Luo DG. A single photoreceptor splits perception and entrainment by cotransmission. Nature. 623, 562–570 (2023).

24．揭示了植物远缘杂交过程中“花粉蒙导效应”的分子机制

瞿礼嘉教授和钟声副研究员团队首次解析了模式植物拟南芥的柱头如何在识别并接受同种/近缘花粉的同时拒绝远缘异种花粉的分子机制，提出了柱头-花粉识别的“锁-钥模型”，阐明了柱头处种/属间生殖障碍形成的机理，从分子层面清晰地解释了“花粉蒙导效应”。该项研究将为打破植物生殖障碍、实现远缘杂交提供理论基础和创新策略。

Molecular mechanism controlling the "Pollen Mentor Effect" in plant distant hybridization

The team led by **Professor Li-Jia QU and Associate Research Professor Sheng ZHONG** elucidated the molecular mechanism by which the stigma recognizes and accepts pollen from the same/closely-related species while rejects pollen from distant species in model plant Arabidopsis thaliana. They proposed the "lock-and-key model" for stigma-pollen recognition, clarifying the molecular regulatory mechanism establishing the interspecific/intergeneric reproductive barrier at the stigma and providing a perfect explanation for the "pollen mentor effect." This discovery lays a theoretical foundation for and provides an innovative strategy to achieving distant plant hybridization via breaking reproductive barriers.



Antagonistic RALF peptides control an intergeneric hybridization barrier on Brassicaceae stigmas, Lan Z.#, Song Z.#, Wang Z., Li L., Liu Y., Zhi S., Wang R., Wang J., Li Q., Bleckmann A., Zhang L., Dresselhaus T., Dong J., Gu H., Zhong S., Qu L-J.*, Cell 186, 4773-4787 (2023).*

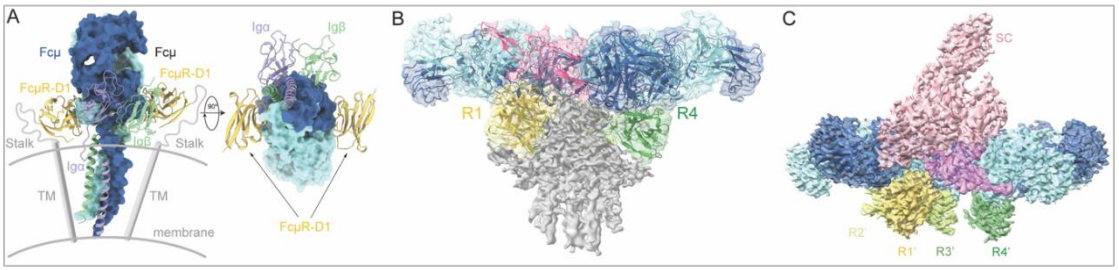
25．阐明免疫球蛋白 IgM 被特异性受体 FcμR 识别的分子机制

IgM 是人体内五类免疫球蛋白之一，在免疫应答早期阶段发挥重要功能。IgM 在人体中以多种形式存在，包括 B 细胞受体复合体中的膜结合型 IgM 单体，分泌到血清中的 IgM 五聚体和六聚体以及处于黏膜表面、包含分泌组分的分泌型 IgM。Fc μR（也称为 Toso 或 Faim3）是哺乳动物中唯一的 IgM 特异性受体，可以与不同形式的 IgM 结合，从而参与 B 细胞发育、免疫系统稳态调控和抗原呈递等过程。**肖俊宇研究员团队**通过结构生物学、生物化学和细胞生物学等手段揭示了 Fc μR 特异性感知不同形式 IgM 的分子机制，为深入理解 IgM 的生物学功能奠定了基础。

Revealing the molecular mechanism of IgM Perception by FcμR

Immunoglobulin M (IgM) is one of the five types of immunoglobulins in the human body, playing an important role in the early stages of the immune response. IgM can exist in several distinct forms, including monomeric,

membrane-bound IgM within the B cell receptor (BCR) complex, pentameric and hexameric IgM in serum and secretory IgM (sIgM) on the mucosal surface. FcμR (also known as Toso or Faim3) is the only IgM-specific receptor in mammals, and participates in B cell development, immune homeostasis and antigen presentation. **Prof. Junyu XIAO**'s group has revealed the molecular mechanism of FcμR's specific recognition of different forms of IgM through structural biology, biochemistry and cell biology methods, laying the foundation for a deeper understanding of the biological function of IgM.



Li, Y., Shen, H., Zhang, R., Ji, C., Wang, Y., Su, C., Xiao, J. (2023). Immunoglobulin M Perception by FcμR. Nature 615:907-912.*

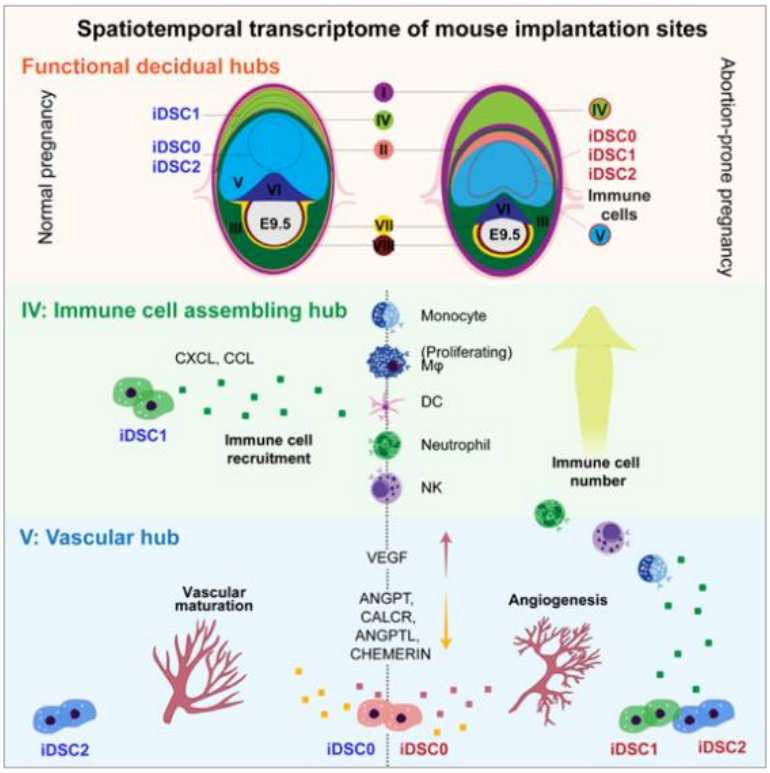
26．时空解析免疫特性的蜕膜基质细胞介导妊娠早期子宫微环境的建立和稳态维持

结合单细胞转录组和单细胞空间转录组，**杜鹏研究员项目组**首次刻画出小鼠妊娠早期着床位点的时空图谱，解析了胚胎着床后子宫微环境的建立和稳态调节过程，包括功能中心的特化，以及各功能中心所发生的复杂生物学事件。同时提示，细胞异常的空间定位与疾病发生发展之间的关系，为单细胞空间组学对疾病或肿瘤的研究提供新的方向和线索。

Spatiotemporal insight into early pregnancy governed by immune-featured stromal cells

Endometrial decidualization connecting embryo implantation and placentation is transient but essential for successful pregnancy, which, however, is not systematically investigated. Here, we use a scStereo-seq technology to spatially visualize and define the dynamic functional decidual hubs assembled by distinct immune, endothelial, trophoblast, and decidual stromal cells (DSCs) in early pregnant mice. We unravel the DSC transdifferentiation trajectory and surprisingly discover a dual-featured type of immune-featured DSCs (iDSCs). We find that immature DSCs attract immune cells and induce decidual angiogenesis at the mesenchymal-epithelial transition hub during decidualization initiation. iDSCs enable immune cell recruitment and suppression, govern vascularization, and promote cytolysis at immune cell assembling and vascular hubs, respectively, to establish decidual homeostasis

at a later stage. Interestingly, dysfunctional and spatially disordered iDSCs cause abnormal accumulation of immune cells in the vascular hub, which disrupts decidual hub specification and eventually leads to pregnancy complications in DBA/2-mated CBA/J mice.



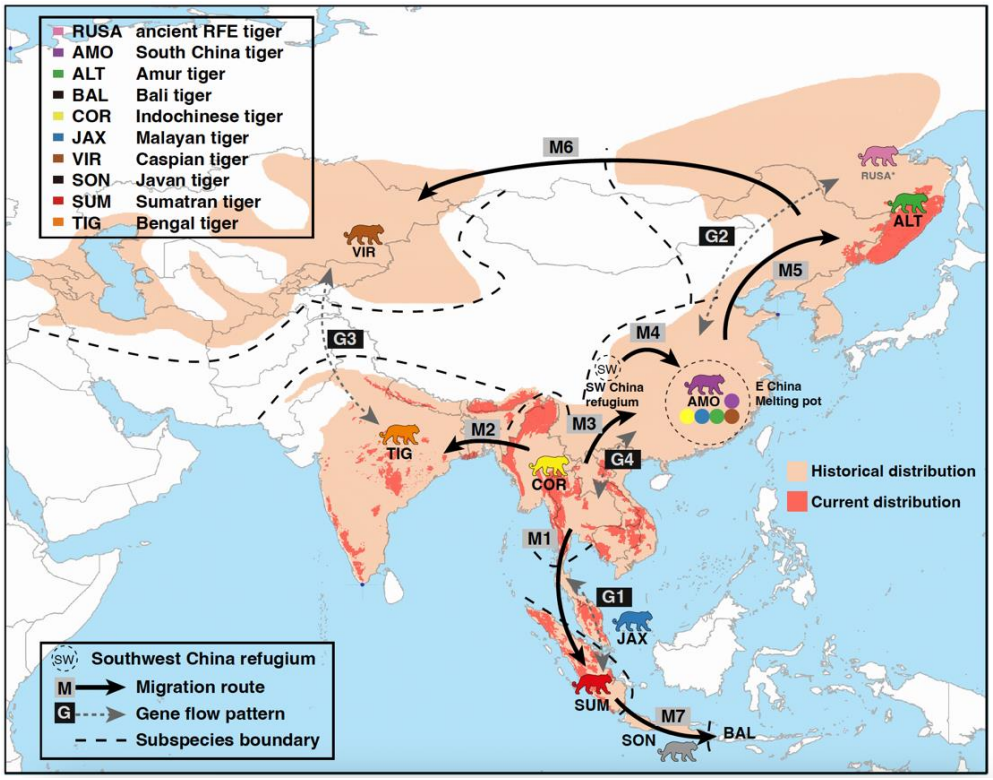
Spatiotemporal insight into early pregnancy governed by immune-featured stromal cells.Yang M, Ong J, Meng F, Zhang F, Shen H, Kitt K, Liu T, Tao W, Du P. Cell. 2023 Sep 28;186(20):4271-4288.e24. 2023）.

27．古 DNA 研究揭示华南虎演化起源

基于古代虎基因组的系统发生学和群体遗传学研究阐明虎的演化史，**罗述金研究员项目组**揭示了中国作为虎的冰期避难所和冰期后“基因大熔炉”的重要地位。华南虎基因组的独特性支持其亚种分类，由此解决了多年来关于华南虎定义不明确的疑问，为全世界虎的保护和遗传管理奠定了科学基础。

Ancient DNA Reveals the Evolutionary Origin of South China Tigers

Phylogenetics and population genetics analysis of ancient tiger genomes inform tiger evolution and reveal China as a post-glaciation genetic melting pot for divergent tiger lineages. Genome-wide monophyly support the South China tiger as a distinct subspecies, hence resolving its longstanding taxonomic controversy and setting the scientific foundation for global tiger conservation and genetic management.



Sun X, Liu YC, Tiunov MP, Gimranov DO, Zhuang Y, Han Y, Driscoll CA, Pan Y, Li C, Pan Y, Velasco MS, Gopalakrishnan S, Yang RZ, Li BG, Jin K, Xu X, Uphyrkina O, Huang Y, Wu XH, Gilbert MTP, O'Brien SJ, Yamaguchi N, Luo SJ (2023). Ancient DNA reveals genetic admixture in China during tiger evolution. Nature Ecology & Evolution 7: 1914-1929.

生物医学前沿创新中心（Biomedical Pioneering Innovation Certer)

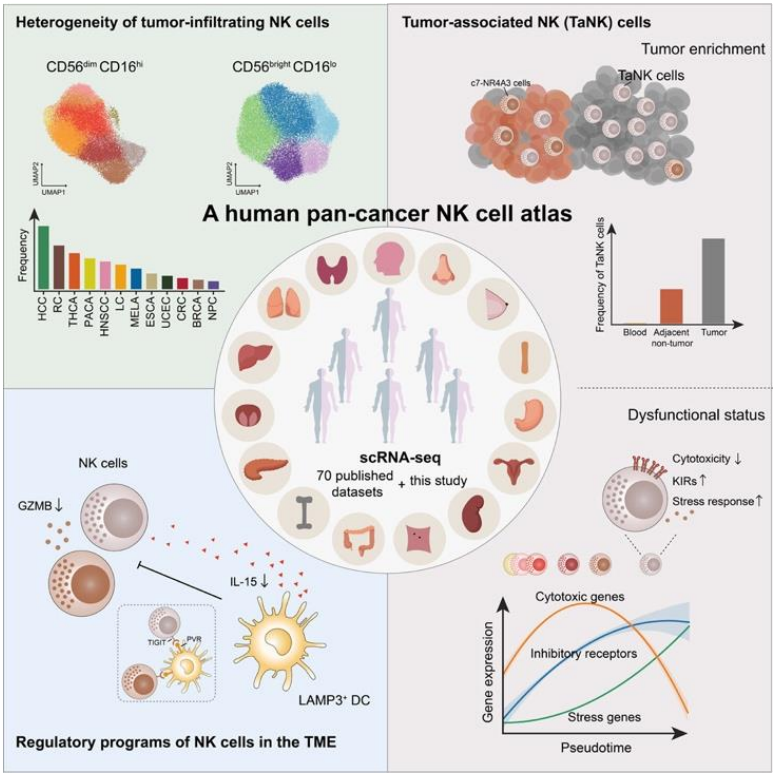
28．通过大规模整合生物信息分析揭示泛癌种自然杀伤细胞异质性

近些年来，通过生物信息学方法赋能新技术，解读复杂现象，已经成为探索和解决重要科学问题的强大助力。**张泽民教授课题组**与合作者以生物信息学数据整合为支撑，通过收集大规模单细胞转录组测序数据，系统刻画了自然杀伤（NK）细胞在不同癌症类型和组织之间的异质性，发现了肿瘤微环境特异富集、杀伤功能异常的 NK 细胞亚类，揭示了 NK 细胞与微环境中其他组分的潜在调控关系。为未来通过更全面的整合分析手段探索新的生物标志物和治疗靶点提供了助力，也为药物研发提供更准确、更全面的数据支持。

A Pan-Cancer Single Cell Panorama of Human Natural Killer Cells

Prof. Zemin ZHANG's lab and collaborators collected a broad spectrum of published and newly generated scRNA-seq data to construct a comprehensive tumor-infiltrating human NK cell atlas and explored the heterogeneity of NK

cells across cancer types and tissues. The comprehensive analyses enhance the current understanding of NK cells from a pan-cancer view, revealing composition changes of NK cell populations as well as their expression pattern. The large-scale data can provide a platform for the exploration of biomarker, and further promote the application of NK cell-based immunotherapy to a broader range of cancer patients.



Tang F, Li J, Qi L, et al. A pan-cancer single-cell panorama of human natural killer cells[J]. Cell, 2023, 186(19): 4235-4251. e20.

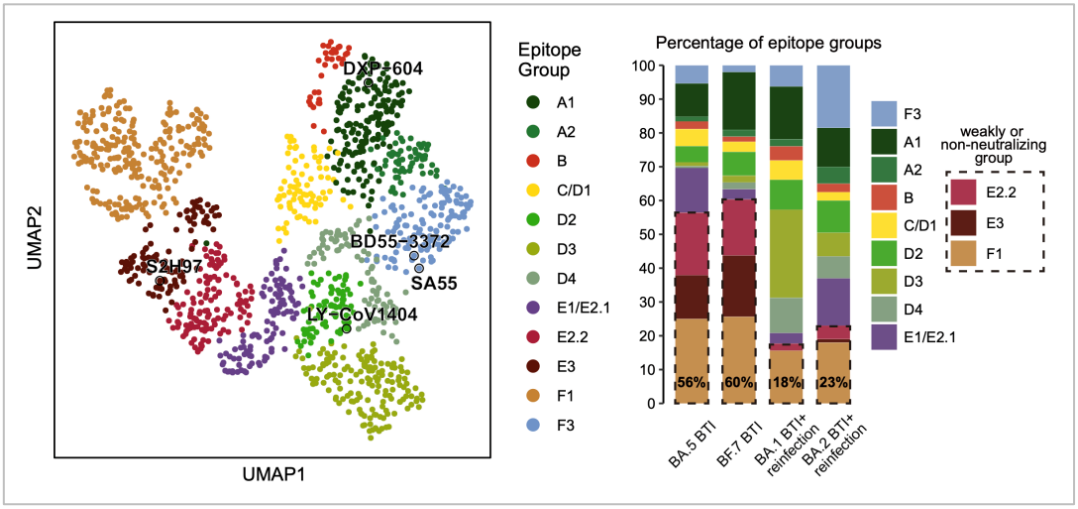
29．揭示新冠病毒免疫印记重塑机制

具有免疫逃逸能力的新冠病毒变异株持续出现，凸显了更新新冠疫苗组分的必要性。**曹云龙研究员课题组**利用免疫小鼠和新冠奥密克戎株感染的人群队列研究了新冠原始株疫苗接种所产生的免疫印记现象，并利用深度突变扫描数据预测了未来 XBB 支系的演化热点。该研究不仅从抗体表位层面深入理解了免疫印记现象，还为全球新冠疫苗的更新和使用策略提供了重要理论指导依据。

Mechanism of Reshaping SARS-CoV-2 Immune Imprinting

The continuous emergence of SARS-CoV-2 variants with immune evasion capabilities underscores the need for updating the components of COVID-19 vaccines. The research group led by **Yunlong CAO** investigated the degree and dynamics of immune imprinting in mouse models and human cohorts, especially focusing on the role of repeated Omicron stimulation. They also utilized deep mutational scanning data to predict the evolutionary hotspots of the future XBB lineage. This research not only provides a deep understanding

of the immune imprinting phenomenon at the level of monoclonal antibody epitopes but also offers important theoretical guidance for the updating and usage strategies of global COVID-19 vaccines.



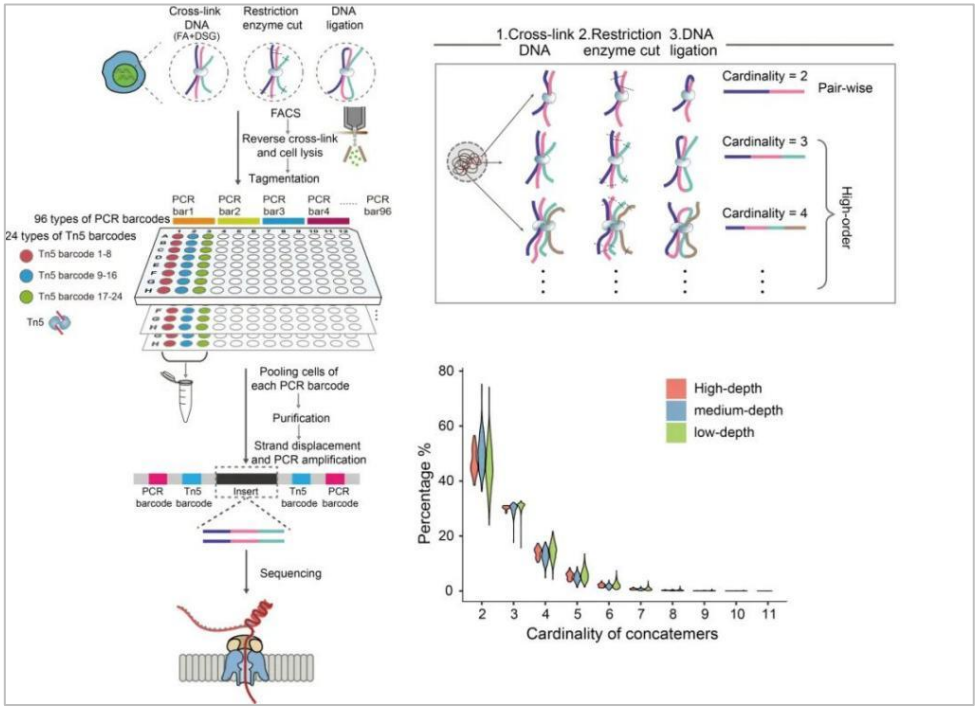
Yisimayi A, Song W, Wang J, et al. Repeated Omicron exposures override ancestral SARS-CoV-2 immune imprinting[J]. Nature, 2023: 1-9.

30．可精准检测单细胞高阶染色质互作的新技术 scNanoHi-C

由于检测技术的限制，对于在单细胞内多个顺式调控元件同时与一个基因启动子之间的高阶相互作用的研究十分有限。**汤富酬教授团队**在国际上率先使用单分子测序平台开发了一种基于邻近连接的单细胞染色质构象捕获方法 scNanoHi-C。该方法实现了在单细胞水平的高阶染色质相互作用检测，并且具有很好的灵活性，能够满足不同的实验需求。

A New Method to Reveal High-Order Chromatin Structures within Individual Cells

The high-order three-dimensional organization of regulatory genomic elements provides a topological basis for gene regulation, but it remains unclear how multiple regulatory elements across the mammalian genome interact within an individual cell. **Prof. Fuchou TANG**'s lab developed a method called scNanoHi-C, which applies Nanopore long-read sequencing to explore genome-wide proximal high-order chromatin contacts within individual cells. Moreover, scNanoHi-C is flexible to satisfy different experimental requirements via alternative sequencing strategies.



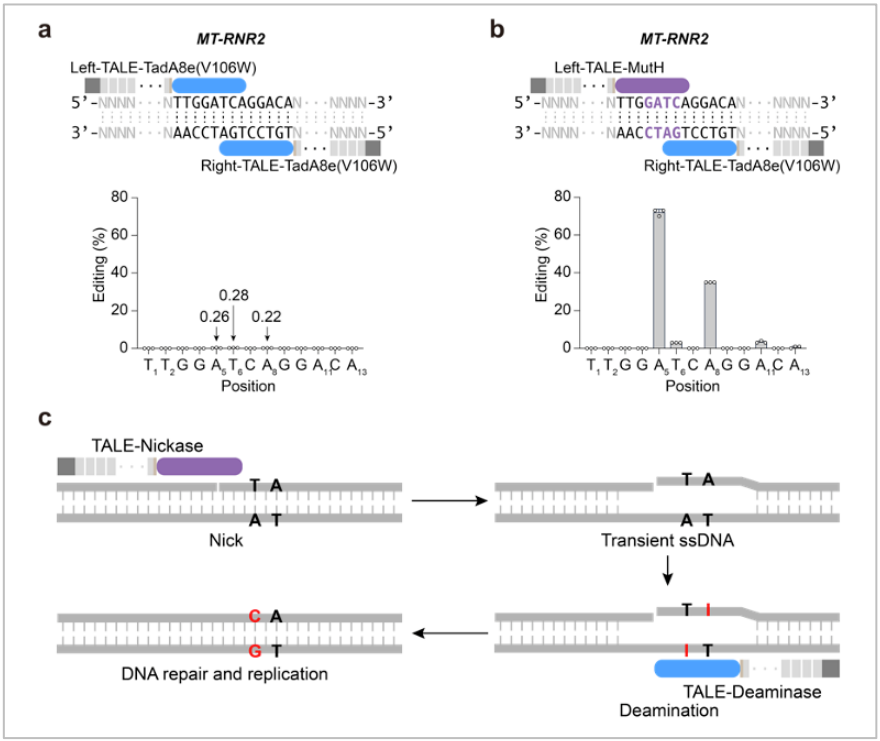
Li W, Lu J, Lu P, et al. scNanoHi-C: a single-cell long-read concatemer sequencing method to reveal high-order chromatin structures within individual cells[J]. Nature Methods, 2023, 20(10): 1493-1505.

31．新型线粒体碱基编辑器 mitoBEs

目前发现的线粒体遗传病中绝大多数都是由线粒体 DNA 点突变导致的，然而现有的基因编辑技术难以进入线粒体继而修正突变。**魏文胜教授课题组**开发了全新线粒体单碱基编辑工具 mitoBEs，它不仅能够高效地实现 A->G 或 C->T 的单碱基编辑，还可以选择性地编辑特定链，其高度特异性和安全性也由全基因组测序证明。更重要的是，使用 mitoBEs 技术修复 LHON 患者来源的细胞中的线粒体基因突变的尝试获得成功，表明该方法对线粒体遗传疾病具有巨大的治疗潜力。

Strand-selective base editing of human mitochondrial DNA

Around 95% of confirmed mitochondrial diseases-related mutations are point mutations that could potentially be corrected using base editing approaches. However, the current CRISPR system encounters obstacles when it comes to mitochondria. **Prof. Wensheng WEI**'s team developed innovative mitochondrial base editing tools mitoBEs (mitochondrial DNA base editors) which offer the capability for strand-selective and high precision A-to-G and C-to-T editing in mitochondrial DNA without large insertions and deletions in mitochondrial DNA. Furthermore, circRNA-encoded mitoBEs successfully corrected pathogenic mitochondrial DNA mutation in cells derived from individuals with LHON. mitoBEs offer a precise, efficient DNA editing tool with broad applicability for therapy in mitochondrial genetic diseases.



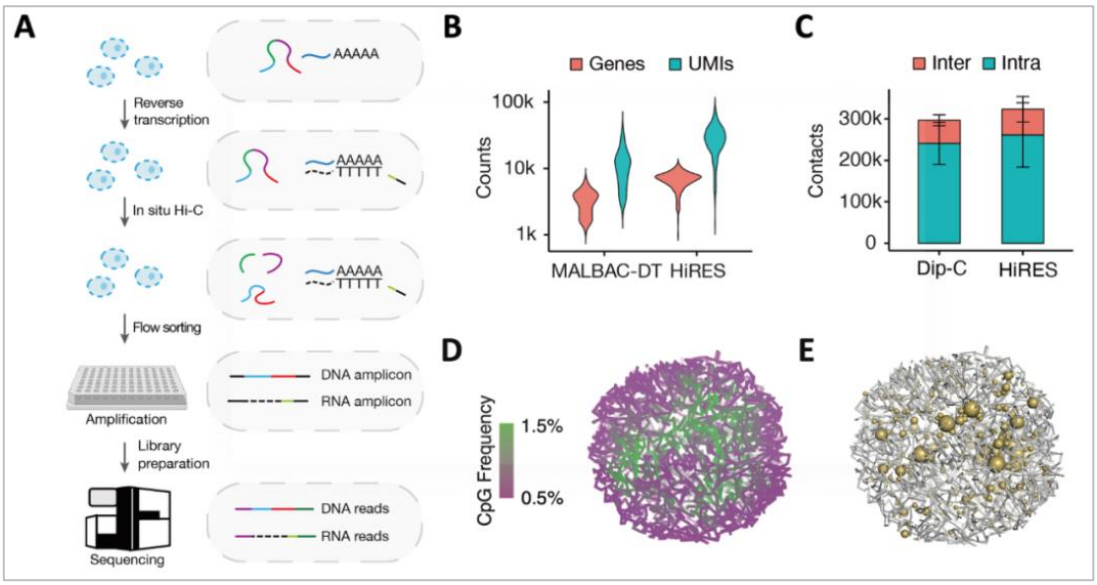
Yi Z, Zhang X, Tang W, et al. Strand-selective base editing of human mitochondrial DNA using mitoBEs[J]. Nature Biotechnology, 2023: 1-12.

32．利用新型单细胞多组学技术 HiRES 揭示三维基因组与基因表达的关系

在高等真核生物中，基因组在细胞核内的三维空间构象对细胞功能至关重要。**邢栋研究员课题组**开发了一种新型单细胞多组学技术 HiRES，首次基于测序方法实现了在单细胞水平对转录组和三维基因组的同时检测。这将有助于今后进一步认识复杂组织器官和丰富细胞类型背景下的染色质三维结构和基因表达之间的关系。

Single-Cell Multi-Omics Technology Revealing the Relationship Between the 3D Genome Architecture and Gene Expression During Development

In higher eukaryotes, the three-dimensional chromatin structure within the cell nucleus plays a vital role in cellular function. A research group led by **Dong XING** reported a novel single-cell multi-omics technique called HiRES (Hi-C and RNA-seq employed simultaneously), which, for the first time, enabled simultaneous detection of the transcriptome and 3D genome at the single-cell level based on sequencing methods. This powerful tool will help scientists further understand the relationship between 3D chromatin structure and gene expression under the context of complex tissue organs and diverse cell types.



Liu Z, Chen Y, Xia Q, et al. Linking genome structures to functions by simultaneous single-cell Hi-C and RNA-seq[J]. Science, 2023, 380(6649): 1070-1076.

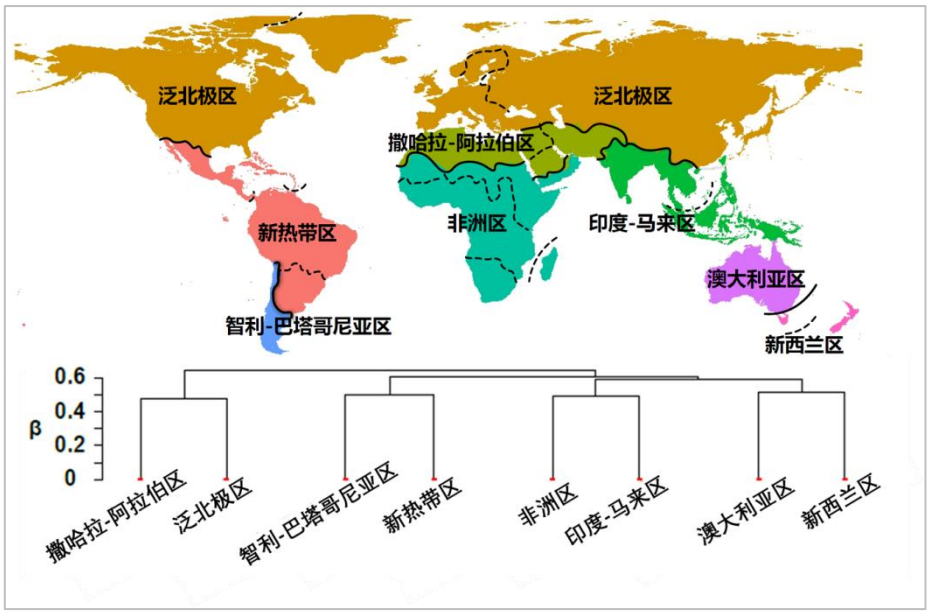
城市与环境学院（College of Urban and Environmental Sciences）

33．联合欧洲学者完成世界植物地理区的划分

王志恒教授团队与合作者建立全球被子植物属水平分布和系统发育树的基础上，对全球植物地理区进行了重新划分，并探讨了植物地理区之间区系分异的时空动态和驱动机制。研究成果发表在 Nature Communications。

Completed the division of Global Plant Geographical Regions

The Macroecology Research Group has published a research paper titled "An updated floristic map of the world" in Nature Communications. Based on the establishment of the global distribution and phylogenetic tree of angiosperm genera, the research team, led by **Professor Zhiheng WANG** from Peking University and Professor Carsten Rahbek from the University of Copenhagen, has redefined the global plant geographical regions. The study delves into the spatiotemporal dynamics and driving mechanisms of floristic differentiation among these plant geographical regions.



Liu, Y., Xu, X., Dimitrov, D., Pellissier, L., Borregaard, M. K., Shrestha, N., Su, X., Luo, A., Zimmermann, N. E., Rahbek, C., & Wang, Z. (2023). An updated floristic map of the world. Nature Communications, 14, 2990.

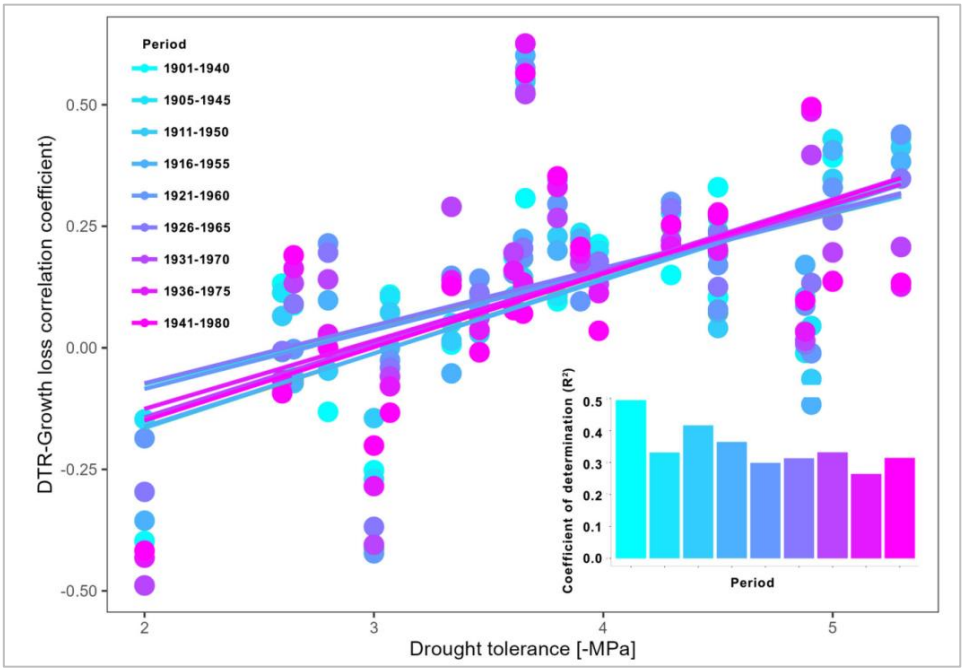
34．揭示昼夜温差与干旱的交互作用对树木生长的影响

基于全球树木年轮数据库中 23 个分布广泛树种的 2327 个样点数据，**刘鸿雁教授研究组**利用结构方程模型、增强回归树模式、线性混合模型等方法量化了上个世纪初以来昼夜温差与干旱的交互作用对树木生长的影响与树种水力指数之间的关系。该研究表明未来昼夜温差变化可能无法缓解干旱对树木生长的不利影响，从而使得干旱对所有树木生长产生更加不利的影响，当前尤其需要关注抗旱性强的树木如何应对气候变化。研究发表在 Nature Communications。

Reveals the Impact of Diurnal Temperature Range and Drought Interaction on Tree Growth

Prof. Hongyan LIU's research team, based on data from 2327 sampling points of 23 widely distributed tree species in the global tree-ring database, quantified the interactive effects of diurnal temperature range and drought on tree growth and their relationship with the hydraulic index of tree species since the early 20th century, using structural equation models, boosted regression tree models, linear mixed-effect models, and other methods.

The research indicates that future changes in diurnal temperature range may not alleviate the adverse effects of drought on tree growth. This suggests that drought could have even more detrimental effects on the growth of all trees, emphasizing the need to pay attention to how drought-resistant trees cope with climate change. The study was published in the journal Nature Communications on October 30, 2023.



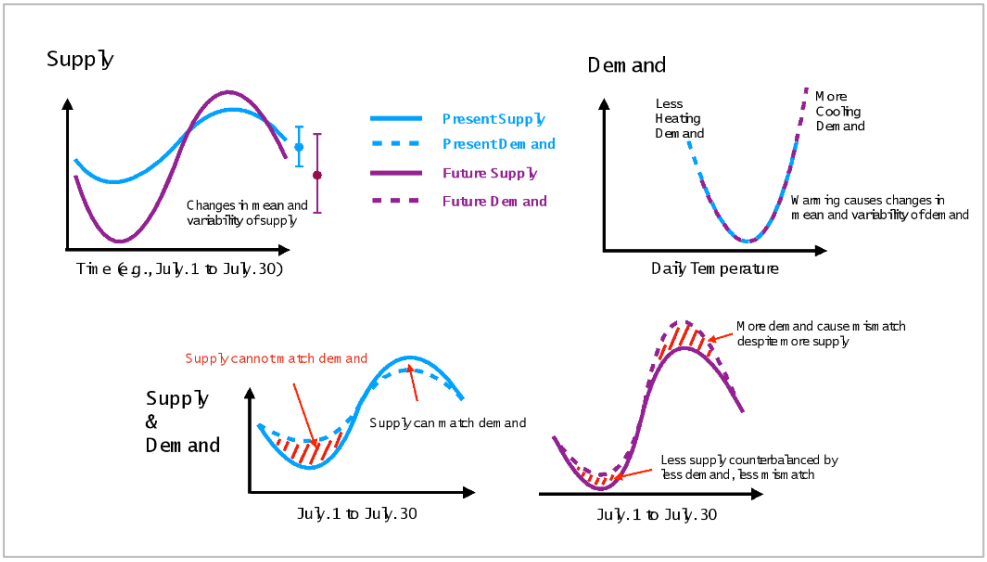
Zhang, X., Rademacher, T., Liu, H., Wang, L., & Manzanedo, R. D. (2023). Fading regulation of diurnal temperature ranges on drought-induced growth loss for drought-tolerant tree species. Nature Communications, 14(1), 6916.

35．联合评估了气候变化下全球风光能源的供需风险

基于参与第六次 IPCC 评估报告的最新地球系统模型所模拟的气候预测资料，**李双成教授团队与合作者**全面评估了气候变化对全球风能和太阳能系统供需匹配的影响。研究结论对于全球能源转型下风能太阳能系统的科学开发规划和气候变化适应具有重要意义。研究成果发表在 Nature Energy（5 年影响因子 63.9）。

Reveals the Impact of Climate Change on the Supply-Demand Match in Global Wind and Solar Energy Systems

Prof. Li Shuangcheng's team, in collaboration with partners, comprehensively assessed the impact of climate change on the supply-demand match in global wind and solar energy systems based on climate prediction data simulated by the latest Earth system models participating in the Sixth IPCC Assessment Report. The research findings hold significant implications for the scientific development planning and climate change adaptation of wind and solar energy systems under global energy transition. The paper was published in the journal *Nature Energy* with a 5-year impact factor of 63.9.



Liu, L., He, G., Wu, M., Liu, G., Zhang, H., Chen, Y., Shen, J., & Li, S. (2023). Climate change impacts on planned supply–demand match in global wind and solar energy systems. Nature Energy, 8(8), 870-880.

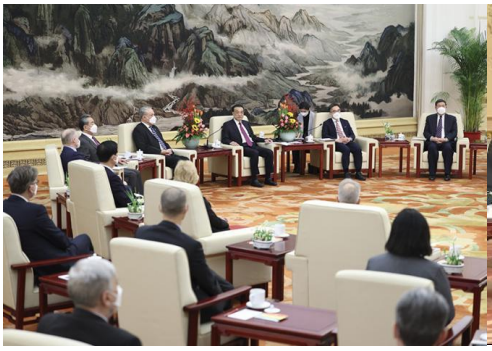
36．Kazuo Isobe 研究员受邀参加李克强总理同外国专家举行新春座谈会

1 月 18 日，时任国务院总理李克强在人民大会堂亲切会见了在华工作的外国专家代表。应科技部邀请，Kazuo Isobe 研究员参加了座谈会。会上，李克强向在华外国专家及亲属致以新春祝福和诚挚问候，感谢大家长期以来关心支持中国改革开放和现代化建设事业，为促进中外交往与合作所作积极贡献，希望外国专家发挥自身优势，多为中国政府工作建言献策。Kazuo Isobe 表示，十分荣幸作为北京大学外国专家代表参加座谈会，在聆听了总理关于中国经济发展和外国人才政策的讲话后，对在华工作生活充满信心和展望。他相信在国家政策支持下，北京大学也将吸引和欢迎更多的外国专家、学者来校访学和工作。

Foreign Faculty Member Dr. Kazuo Isobe was Invited to Attend the "New Year Symposium with Foreign Experts" Held by Premier Li Keqiang

On the afternoon of January 18th, Premier Li Keqiang warmly met with representatives of foreign experts working in China at the Great Hall of the People. At the invitation of the Ministry of Science and Technology, our researcher, Kazuo Isobe, participated in the symposium. During the meeting, Premier Li Keqiang extended his heartfelt New Year wishes and sincere greetings to foreign experts and their families in China. He expressed gratitude for their long-term concern and support for China's reform, opening-up, and modernization, recognizing their positive contributions to promoting exchanges and cooperation between China and foreign countries. Premier Li hoped that foreign experts would leverage their expertise to provide valuable suggestions

for the Chinese government's work.
Kazuo Isobe expressed great honor as the representative of foreign experts from Peking University at the symposium. After listening to the Premier's speech on China's economic development and policies for foreign talent, he expressed confidence and optimism about working and living in China. He believes that with the support of national policies, Peking University will continue to attract and welcome more foreign experts and scholars for academic visits and work, actively participating in the international cooperation and exchanges.

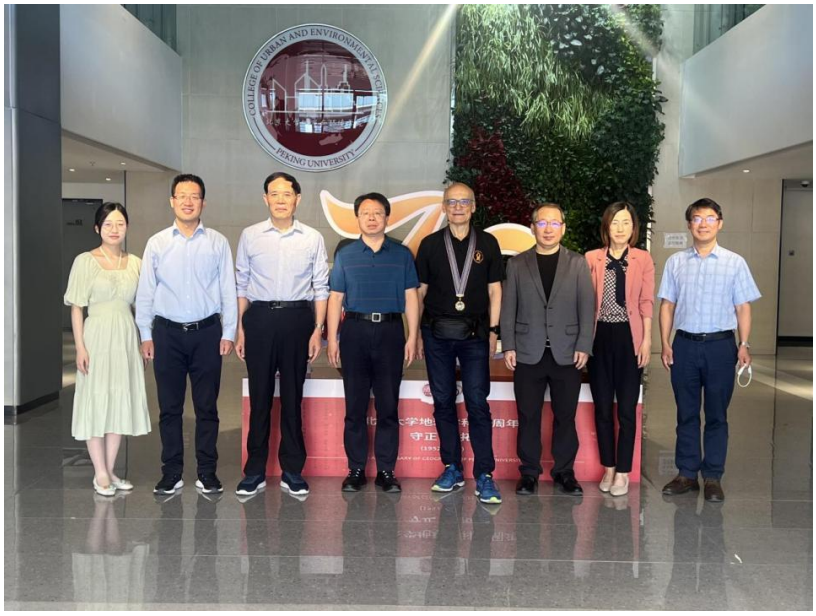


37．客座教授 Bernhard Schmid 获北京市“国际合作中关村奖”

学院客座教授、瑞士苏黎世大学教授 Bernhard Schmid 于 2023 年 5 月荣获北京市科学技术奖国际合作中关村奖，并受邀出席“中关村论坛”。5 月 23 日，学院为 Bernhard Schmid 教授举行了颁奖仪式。

Professor BERNHARD Walter SCHMID Brandli Received Beijing Science and Technology Award - Zhongguancun Award for International Cooperation

On May 23, 2023, the College of Urban and Environmental Sciences at Peking University hosted the award ceremony for the Beijing Science and Technology Award - Zhongguancun Award for International Cooperation, honoring Professor BERNHARD Walter SCHMID Brandli. Dean He Canfei warmly welcomed Professor BERNHARD Walter SCHMID Brandli's visit on behalf of the college. Dean He expressed that Professor B. Schmid has maintained close collaboration with the College of Urban and Environmental Sciences, significantly enhancing the international research level of the college.
Professor B. Schmid delivered an acceptance speech, expressing gratitude for the long-standing care and support from both institutions. He also expressed anticipation for future collaborations and exchanges with an increasing number of young Chinese scholars.



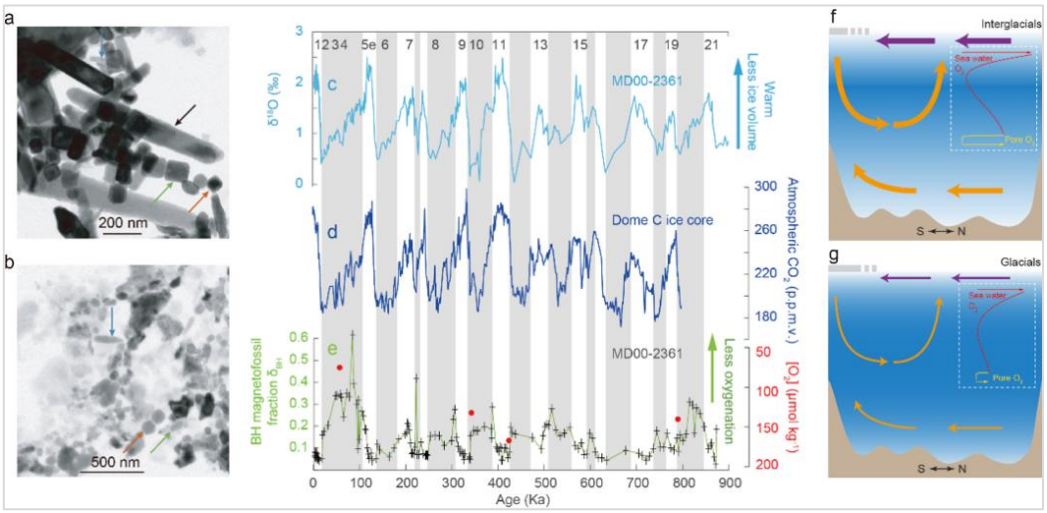
地球与空间科学学院 (School of Earth and Space Sciences)

38．纳米磁化石揭示海洋碳库变化对大气 CO2 的调节作用

海洋溶解氧可以反映海洋“生物碳泵”调控大气 CO_2 浓度的强度。**常燎研究员团队与合作者**创新运用海洋环境中的纳米磁化石记录，重建了过去百万年以来冰期-间冰期气候转换过程中印度洋海洋溶解氧演化规律及其驱动过程，结果表明冰期印度洋溶解氧显著降低和碳库储量增强，揭示了海洋碳库对于调节大气 CO_2 浓度的重要过程，为理解海洋碳库自然演化对于气候变化的调控规律，以及海-气交换作用提供了重要启示。

Magnetofossil records reveal the role of ocean carbon storage in regulating atmospheric CO2

Ocean oxygenation level is crucial in regulating atmospheric CO_2. **Prof. Chang Liao's team** and collaborators utilized a novel magnetofossil approach to reconstruct Indian Ocean oxygen content over the last ~900 ka, and found a recurrence of lower O_2 and increased carbon storage in glacial Indian Ocean. The study reveals the important role of oceanic respired carbon pool in regulating atmospheric CO_2, and sheds light on understanding the natural process of oceanic carbon storage and ocean-atmosphere exchange under climate change.



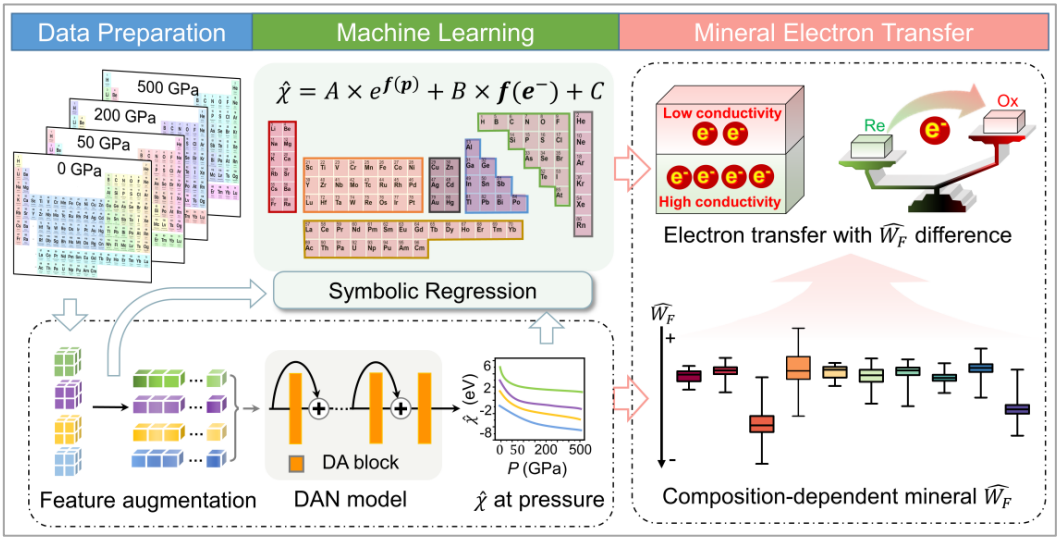
Indian Ocean glacial deoxygenation and respired carbon accumulation during mid-late Quaternary ice ages. L. Chang, B. Hoogakker, D. Heslop, X. Zhao, A. Roberts, P. De Deckker, P. Xue, Z. Pei, F. Zeng, R. Huang, B. Huang, S. Wang, T. Berndt, M. Leng, J. Stuut, R. Harrison. Nature Communications, 14: 4841 (2023).

39．深度学习揭示表层与深部地球电子转移的定量规律

因矿物界面电子转移所驱动的地球碳循环、非生物途径产氢以及深部地质体电导异常等重要地质现象一直缺乏普适性理论认识。**鲁安怀教授和李艳副教授研究组**与合作者应用深度学习建立了任意压力（0-500 GPa）下 96 种元素电负性与电子构型之间的可解释公式，定量揭示并预测了地球不同压力下矿物的电子转移活性。该研究首次为复杂地球系统中因电子转移所驱动的物质氧化还原化学活性与电导等物理属性变化提供了可量化的理论依据。

Electron transfer rules at surface and deep Earth informed by deep learning

There has been a lack of universal and theoretical understanding of important geological phenomena driven by electron transfer at mineral interfaces such as the Earth's carbon cycling, hydrogen production from abiotic processes, and electrical conductivity anomalies of deep geological bodies. **Prof. Anhuai LU and Associate Prof. Yan LI** research team and collaborators applied deep-learning methods to establish an interpretable formula describing the quantitative dependence of electronegativity of 96 elements on electronic configuration under arbitrary pressure (0-500 GPa). This work quantitatively reveals and predicts the electron transfer reactivity of minerals under different pressures, and firstly provides a quantifiable theoretical basis for the changes in physical properties driven by electron transfer such as redox chemical reactivity and electric conductivity of materials in complex Earth systems.



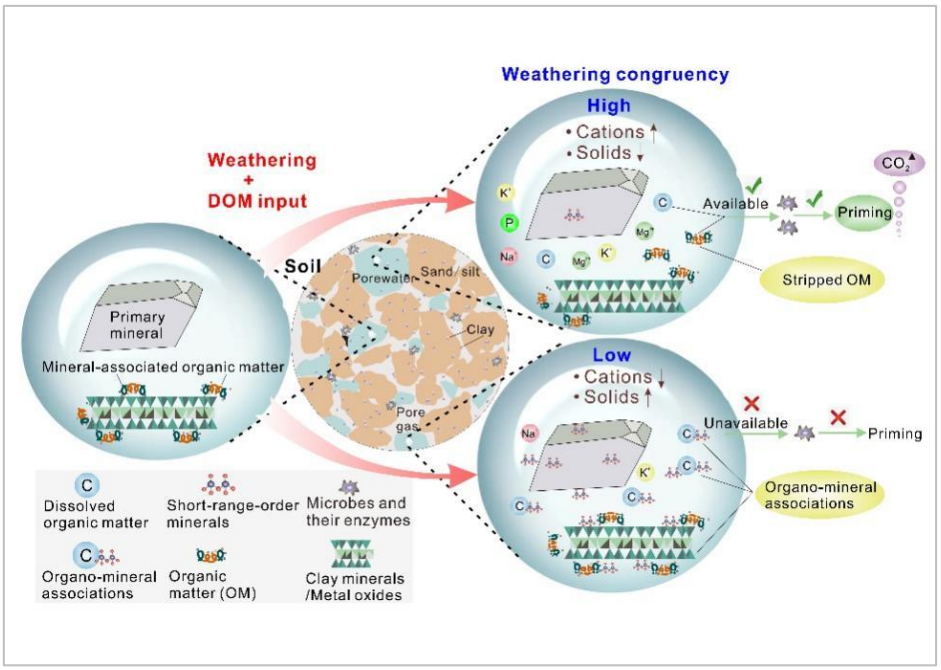
Electron transfer rules of minerals under pressure informed by machine learning. Y. Li, H. Wang, Y. Li, H. Ye, Y. Zhang, R. Yin, H. Jia, B. Hou, C. Wang, H. Ding, X. Bai, A. Lu. Nature Communications 14, 1815 (2023).

40．揭示地表矿物-微生物-有机质耦合作用新机制

地表矿物、微生物与有机质之间内在作用机制，特别是矿物风化作用在微生物激发效应中扮演的角色尚未被揭示与认知。**鲁安怀教授团队**与合作者研究发现，地表矿物风化作用与微生物激发效应之间存在着密切联系。该研究结果表明，地表无机界矿物与有机界微生物和有机质之间耦合作用关系远比人们之前认识到的要丰富得多。为深时地球矿物-微生物共演化、地球元素循环影响全球气候变化研究提供了新的启示。

Revealing a new coupling mechanism of surface minerals-microorganisms-organic matter

The intrinsic interaction mechanism between minerals, microorganisms, and organic matter, especially the role of mineral weathering in priming effects, has not yet been revealed and understood. Professor Lu Anhuai's team and collaborators have discovered that there is a close connection between mineral weathering and priming effect. The results of this study show that the coupling relationship between surface inorganic minerals, microorganisms and organic matter is much richer than previously recognized. It provides new enlightenment for the study of the co-evolution of earth minerals and microorganisms in deep time and the impact of Earth's element cycles on global climate change.



Mineral weathering is linked to microbial priming in the critical zone. Fang, Q., Lu, A., Hong, H., Kuzyakov, Y., Algeo, T. J., Zhao, L., Olshansky, Y., Moravec, B., Barrientes, D., Chorover, J. *, 2023. Nature Communications 14, 345.*

41．地球内核差速旋转发生反转

地球的内核处在液态外核的中心。**宋晓东教授团队**研究显示此前发现的内核“超速旋转”（转速略大于地球自转）在 2009 年左右已经停止，并于近十余年逐渐相对地表反向旋转，处于长周期的振荡模式。这与其它的地球观测（地球自转、磁场、平均气温变化等）中的六七十年周期相关联，揭示了我们这个动态星球从最中心到地表可能存在一个神秘的耦合共振系统。

Differential rotation of Earth’s inner core is in reversal

Inner core is at the centre of Earth, surrounded by the liquid outer core. **Prof. Xiaodong SONG**'s team finds that the previously discovered inner-core "superrotation" (rotating slightly faster than Earth’s surface) stopped around 2009, and has gradually reversed since then. The inner-core rotation shows an oscillatory pattern with a period of about 6 to 7 decades, which is correlated with a few other Earth observations (the Earth's rotation, magnetic field, and global sea level rise and mean surface temperature), revealing that our dynamic planet may have a mysterious coupling resonance system from its centre to the surface.

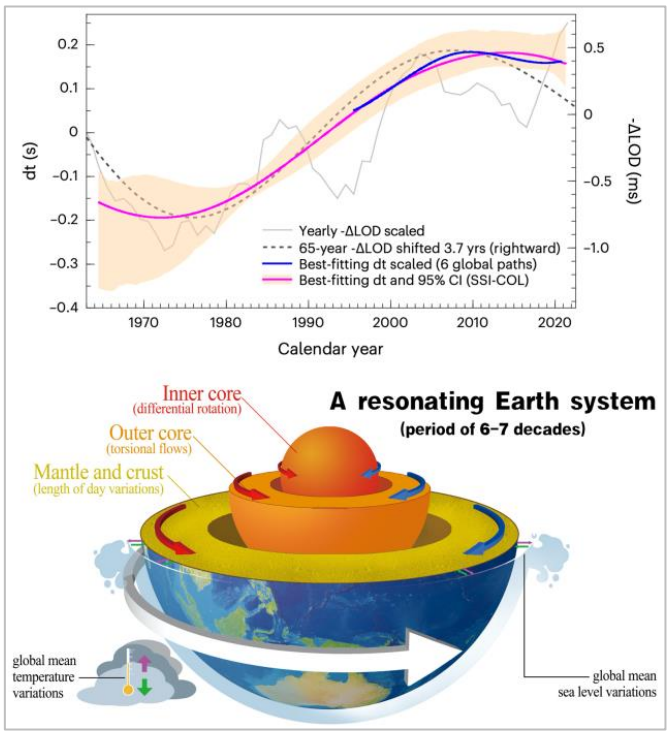


Figure . Correlation of the observed inner-core differential rotation and the length-of-day variation (top) and a hypothesized resonating earth system from the center to the surface of the Earth.

Y. Yang and X. Song. Multidecadal variation of the Earth's inner-core rotation. Nature Geoscience 16, 182–187 (2023). https://doi.org/10.1038/s41561-022-01112-z.*

42．宗秋刚教授当选美国地球物理联合会会士

宗秋刚教授带领研究团队成功解码太空中神秘的动理学阿尔芬波，提出了一种新的测量波动垂直波长的方法，开拓了诊断空间等离子体中动理学阿尔芬波的新思路，并将其成功应用于 MMS 卫星观测到的动理学阿尔芬波事件。

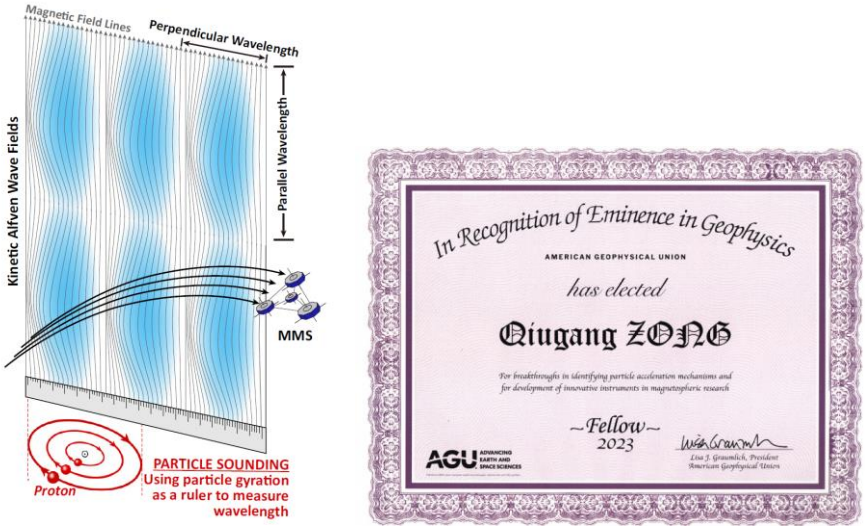
9 月，**宗秋刚教授**因在识别太空磁层粒子加速机制和发展新型探测载荷方面取得突破性进展而入选美国地球物理联合会（AGU）会士，是中国大陆空间物理领域第一位获此殊荣的科学家。

Prof. Qiugang Zong being elected as the American Geophysical Union Fellow

Kinetic Alfvén waves (KAWs) are ubiquitous throughout the plasma universe. Although they are broadly believed to provide a potential approach for energy exchange between electromagnetic fields and plasma particles, neither the detail nor the efficiency of the interactions has been well-determined yet. The primary difficulty has been the paucity of knowledge of KAWs' spatial structure in observation. Here, we apply a particle-sounding technique to Magnetospheric Multiscale mission data to quantitatively determine the perpendicular wavelength of KAWs from ion gyrophase-distribution

observations. Our results show that method and results shown here provide a basis for unraveling the effects of KAWs in dissipating energy and accelerating particles in a number of astrophysical systems, e.g., planetary magnetosphere, astrophysical shocks, stellar corona and wind, and the interstellar medium.

In September 2023, **Prof. Qiugang ZONG** was elected as a Fellow of the American Geophysical Union (AGU) for his breakthroughs in identifying particle acceleration mechanisms and development of innovative instruments in magnetospheric research, with a total of 54 people worldwide receiving this honor. Professor Zong Qiugang is the first scientist in the field of space physics in Chinese mainland to receive this honor.



Liu, ZY., Zong, QG., Rankin, R. et al. Particle-sounding of the spatial structure of kinetic Alfvén waves. Nat Commun 14, 2088 (2023). https://doi.org/10.1038/s41467-023-37881-3.

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

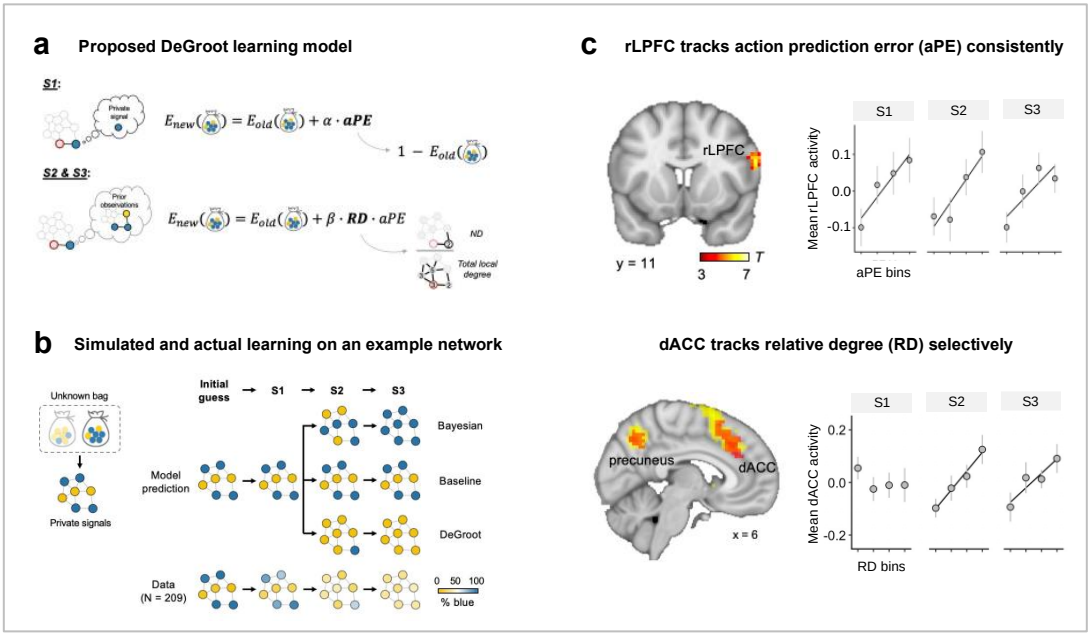
43．人脑分布式社会学习的认知和神经计算机制

社会动物身处各种各样的社会网络之中，这些网络关系决定了我们和谁互动，从谁那里获取信息，以及获得什么样的信息，从而深刻地影响着我们的思想和行为。**朱露莎研究员课题组**首次揭示了社会网络中人脑如何整合不同信息源的信息作出决策的认知和神经过程。通过脑成像、社会网络分析、强化学习等多学科方法，说明社会网络的结构对人脑决策过程的影响机制和后果：经由背侧前扣带皮层的对信息整合的调节，决策系统给那些更加“四通八达”的信息源施加更高的权重，低估甚至忽略可能掌握了部分真理的其他信息源；在理论和实验中，这种策略可能导致虚假信息的传播和错误共识的形成。该工作拓展了社会神经科学和决策研究的边界，为研究复杂环境社会行为的神经机制贡献了新颖、可拓展的实

验方法和计算模型。

The human brain biases integration of information passed through social networks

In a connected society, our beliefs and choices are shaped by the information received from others. Despite extensive studies on how social networks affect behavior at the population level, little is known about how the human brain makes decisions in networked environments. **Lusha ZHU**'s team shows that the brain flexibly weighs information received from a social contact according to how well-connected that contact is on the network responsible for information transmission. Theoretically and empirically, this network-dependent algorithm of social learning can give rise to collective maladaptation, including the propagation of misinformation and biased social consensus.



Jiang, Yaomin, Mi, Qingtian & Zhu, Lusha. Neurocomputational mechanism of real-time distributed learning on social networks. Nature Neuroscience. 26, 506–516 (2023).

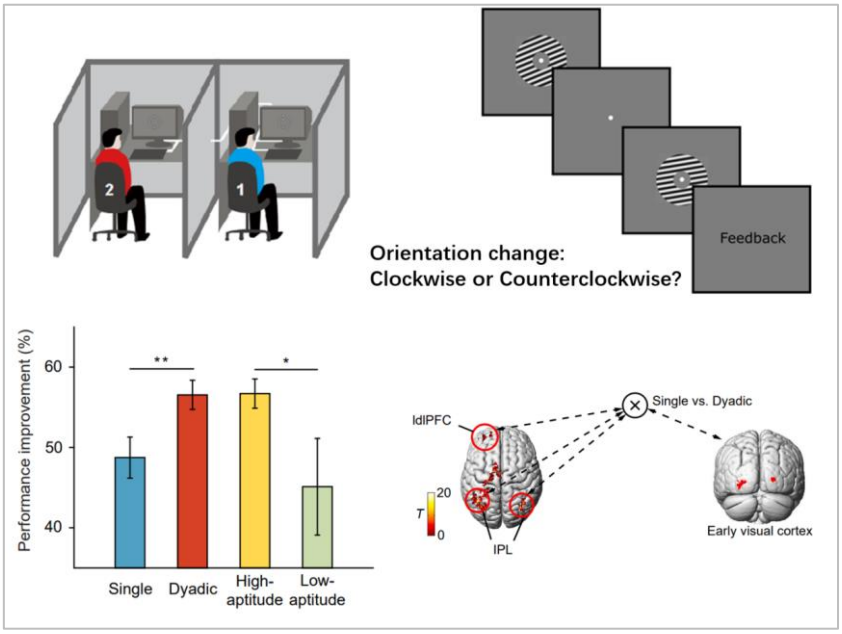
44．双人知觉学习提升学习效果和脑可塑性

对脑可塑性的研究和开发意义重大。**方方教授团队**首次揭示了社会情境对于视觉知觉学习的促进作用以及相关的神经机制。该工作提示以复杂系统的视角研究真实世界脑可塑性的必要性，并展示了一种安全、高效的认知增强方法。

Dyadic perceptual learning facilitates learning efficiency and brain plasticity

The significance of researching and developing brain plasticity is profound. **Prof. Fang FANG**'s team has for the first time demonstrated how social contexts significantly facilitate visual perceptual learning and elucidated the underlying

neural mechanisms. This research underscores the importance of investigating brain plasticity in the real world from the perspective of complex systems and presents a safe and efficient method of cognitive enhancement.



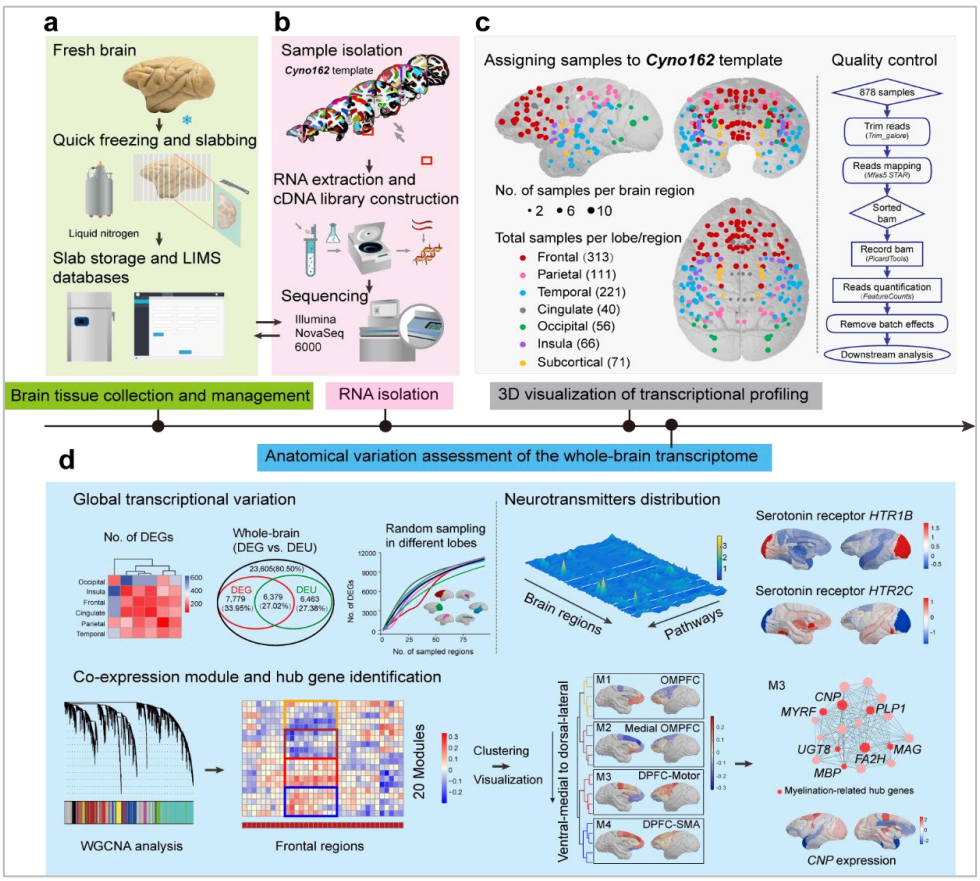
Zhang, Y., Bi, K., Li, J., Wang, Y., & Fang, F. (2023). Dyadic visual perceptual learning on orientation discrimination. Current Biology, 33(12), 2407-2416.

45．开启灵长类影像转录组学研究新篇章

非人灵长类模式动物迄今都缺乏与人类脑图谱相对应的转录组学数据，成为了掣肘脑科学领域发展的瓶颈。**王征研究员实验室**完整地覆盖食蟹猴全脑各个分区的转录组图谱，并以此结合猕猴磁共振脑影像大数据，开展猕猴大脑皮层解剖结构特征的基因表达分析，鉴定了 1005 个与大脑皮层厚度紧密相关的基因集，进而使用猕猴视皮层的单细胞测序数据注释了相应的细胞亚型和功能通路。

Open a new chapter of imaging transcriptomics in primates

Although nonhuman primate is phylogenetically in close proximity to human being, a complete anatomically-defined atlas of brain transcriptomics in MRI coordinates is still lacking. Here we generate complementary bulk RNA-sequencing dataset of 819 samples from 110 brain regions and single-nucleus RNA-sequencing dataset, and neuroimaging data from 162 cynomolgus macaques, to examine the link between brain-wide gene expression and morphometric changes in individuals. These findings demonstrate a brain-wide transcriptomic atlas of macaque monkey as a stepping stone, which allows an integrative analysis of microscale attributes including single-cell/nucleus transcriptomic atlas and a wide variety of macroscale neuroimaging attributes that inform brain development, morphology and function.



Bo TT, Li J, Hu GL, Zhang G, Wang W, Lv Q, Zhao SL, Qin M, Yao XH, Wang MY, Wang GZ, Wang Z, Brain-wide and cell-specific transcriptomic insights into MRI-derived cortical morphology in macaque monkeys, Nature Communications, 2023, 14: 1499-1514.

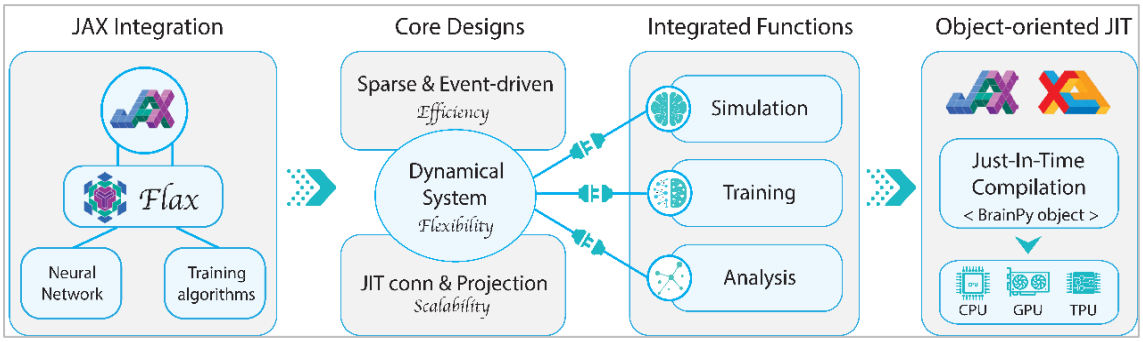
46．脑动力学仿真与类脑计算的通用编程平台

吴思教授团队研发了脑动力学仿真与类脑计算的通用编程平台 BrainPy。该软件使用即时编译方法，开发了一系列简单易学、灵活高效且高度可扩展的脑动力学仿真工具，包括模型定义、模拟、训练和分析等功能。在 GitHub 上开源两年以来，下载量超过 15 万，远超同期其它脑仿真软件，连续两年获得 OpenI 的优秀项目奖，以 BrainPy 为基础的教材《神经计算建模实战》也被国内高校和研究所广泛使用。

General-purpose Programming Platform for Brain Dynamics and Brain-inspired Computing

The team of **Prof. Si WU** has developed a general-purpose programming platform for brain dynamics and brain-inspired computing, called BrainPy. BrainPy adopts the just-in-time compilation technology and develops a number of easy-to-use, flexible and extensible tools for brain dynamics simulation, including model construction, simulation, training and analysis. Since open on GitHub for two years, BrainPy has received over 150,000 downloads, far more than other brain simulators in the same period, and has won Excellent Project

Award from OpenI for two consecutive years. The book "Neural Modelling in Action" based on BrainPy has been used as a text book in many universities and institutes.

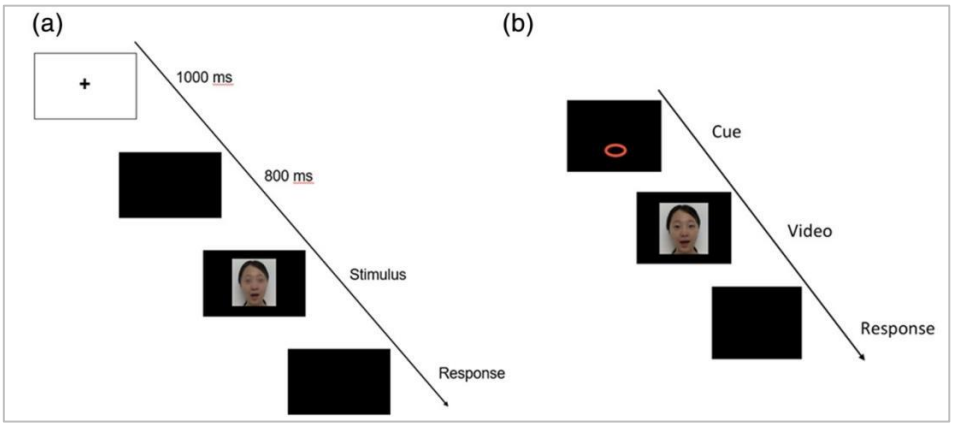


47．增加孤独症儿童对说话者嘴部的注视能提升其视听言语整合

孤独症儿童的视听言语整合缺陷与其注视说话者嘴部较少的注意有关。**易莉研究员团队与陈立翰副教授团队**合作发现，模糊说话者眼部和引导孤独症儿童看向说话者嘴部能增长孤独症儿童对说话者嘴部的注视时间，增强其在 McGurk 任务（即视觉口型和听觉语音整合的错觉效应）上的表现。该工作深入阐释了对面部的注视与视听言语整合的关系，为干预孤独症儿童的视听言语整合提供了新思路。

Increasing audiovisual speech integration in autism through enhanced attention to mouth

Children with autism (AC) exhibit deficits in integrating audiovisual speech, linked to their decreased time spent looking at the mouth. Research by **Li YI's team and Lihan CHEN's team** revealed that blurring the speaker's eyes or directing attention to the speaker's mouth enhances both mouth-looking time and audiovisual speech integration in AC during the McGurk task. This study deepens our understanding of the connection between facial attention and audiovisual speech integration, offering valuable insights for creating specialized support to improve audiovisual speech integration in autistic children.



Increasing audiovisual speech integration in autism through enhanced attention to mouth. S. Feng, Q. Wang, Y. Hu, H. Lu, T. Li, C. Song, J. Fang, L. Chen, L. Yi. Developmental Science 26, e13348 (2023).

建筑与景观设计学院（College of Architecture and Landscape）

48．俞孔坚教授荣获美国国家设计奖与奥伯兰德奖，并应邀在 COP28 会上做两场报告

俞孔坚教授带领团队长期从事风景园林和景观规划设计的研究与实践，在应对全球气候变化、解决城市洪涝和修复地球生态等方面做出了卓越贡献。8 月，俞孔坚教授荣获 2023 年度美国国家设计奖中的风景园林设计奖；10 月，俞孔坚教授荣获美国文化景观基金会颁发的 2023 年奥伯兰德奖。11 月 30 日-12 月 12 日，《联合国气候变化框架公约》第二十八次缔约方大会（COP28）在阿联酋迪拜召开，俞孔坚教授受世界自然保护联盟（IUCN）与亚洲基础设施投资银行（AIIB）的邀请，分别在两场高级别会议上做报告，向世界介绍基于自然的解决方案（NbS）实践的中国经验，展现景观设计师在减缓和适应气候变化方面发挥的关键作用。

Prof. KongjianYU awarded the National Design Award and the Cornelia Hahn Oberlander Prize, and invited to give two speeches on COP28

Prof. Kongjian YU has led the team in the long-term research and practice of landscape gardening and landscape planning and design, and has made outstanding contributions to addressing global climate change, solving urban flooding and restoring the earth's ecology. In this August, Prof. Kongjian YU was awarded the National Design Award for Landscape Architecture in this year. In this October, the Cultural Landscape Foundation (TCLF) announced that Prof. Kongjian YU won the 2023 Cornelia Hahn Oberlander Prize. The 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) was held in Dubai, United Arab Emirates from November 30 to December 12, 2023. As an early practitioner and important promoter of NbS, Professor Yu Kongjian was invited by the International Union

for Conservation of Nature (IUCN) and the Asian Infrastructure Investment Bank (AIIB) to give presentations at two high-level conferences, introducing the Chinese experience of NbS practice to the world and demonstrating the key role played by landscape architects in mitigating and adapting to climate change.

49．推进水利部水生态保护和水利遗产重点实验室（筹）的建设

以水生态保护与修复为研究对象，针对我国城镇化和工业化背景下水生态保护与修复、水利遗产研究面临的理论与实践前沿，系统进行学术研究、教学工作和实践应用，开展了基于“源-流-汇”框架的流域雨洪韧性机制及优化研究，建立了海绵流域方法(SWA)，并将其应用于郑州泗水流域；构建了模式化景观途径营造低维护海绵城市；开展了以泰国曼谷班加科特森林公园为代表的多项应用工程实践。在人才培养和队伍建设取得新成绩，积极开展国内外学术交流合作以及科普宣传活动。

Construction of the Key Laboratory of Water Ecology Protection and Hydraulic Heritage of the Ministry of Water Resources by the College of Architecture and Landscape Architecture (Preparation)

Taking water ecology protection and restoration as the research object, the laboratory has systematically carried out academic research, teaching work and practical application in response to the theoretical and practical frontiers of water ecology protection and restoration and water conservancy heritage research in the context of China's urbanization and industrialization, and has carried out research on the resilience mechanism of rainfall and flooding in watersheds and optimization based on the framework of "source-flow-sink", and established the Sponge Watershed Approach (SWA) and applied it to the Si River watershed in Zhengzhou. The laboratory has constructed a patterned landscape pathway to create low-maintenance Sponge Cities, and carried out a number of applied practices represented by the Bangkat Kotte Forest Park in Bangkok, Thailand. New achievements have been made in talent cultivation and team building, active academic exchanges and cooperation at home and abroad, as well as science popularization and publicity activities.

50．共建基于自然的解决方案全球创新中心

推动与世界自然保护联盟（IUCN）于 2023 年 8 月 29 日签署谅解备忘录，目标是为双方提供一个合作框架，以强大的学术力量支持基于自然的解决方案（NbS）相关研究和实践，共同建设 NbS 全球创新中心，促进中国及其他地区的自然保护和可持续发展，并培养保护专业人员和相关领域学生的能力。同时，与自然资源部国土整治中心共建 NbS 亚洲中心，学院为 NbS 亚洲中心创新基地。

PKU-IUCN Joint Global Innovation Center for Nature-Based Solutions (NbS)

The College of Architecture and Landscape Architecture has prompted the signing of a Memorandum of Understanding (MoU) between IUCN and Peking University on August 29, 2023, with the goal of providing a framework for collaboration between the two parties to support nature-based solutions (NbS)-related research and practice with a strong academic presence, to jointly build a NbS Global Innovation Center which promotes nature conservation and sustainable development in China and elsewhere, and capacity-building for the conservation professionals' and students in related fields. Meanwhile, together with the Center for Land Reorganization of the Ministry of Natural Resources, we are building the NbS Asia Center, and the College is the innovation base of the NbS Asia Center.

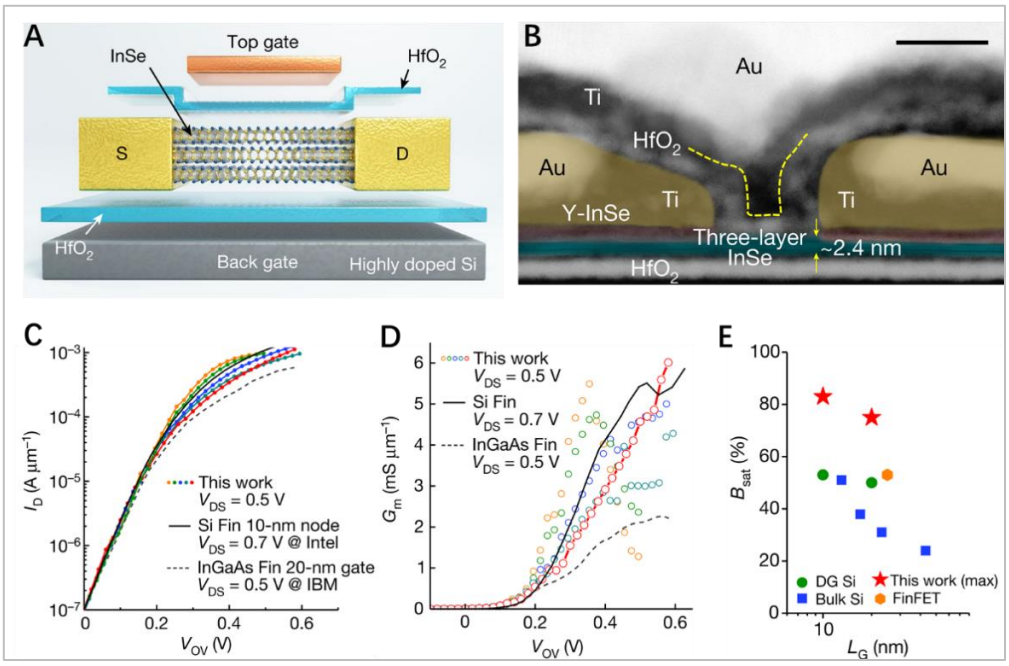
电子学院（School of Electronics）

51．超越硅极限的弹道二维晶体管

彭练矛教授和邱晨光研究员团队构筑了 10 纳米弹道二维硒化铟晶体管,实现有史以来晶体管最高室温弹道率 83%，首次推进二维晶体管实际性能超过业界 Intel 硅基 Fin 晶体管和 IRDS 预测的硅极限。将二维晶体管的电压降到 0.5V，延时仅为硅基极限的 1/4，功耗降为 1/3，这是国际上迄今速度最快能耗最低的二维晶体管。

Ballistic two-dimensional transistors with performance exceeding silicon limit

Prof. Lian-Mao PENG and Chenguang QIU fabricated high-performance 2D InSe FETs with gate-length scaled down to 10 nanometers and room-temperature ballistic ratios of up to 83 percent. The scaled 2D InSe FETs show excellent on-state performance even with an ultralow supply voltage of 0.5 volts, exceeding those of state-of-the-art silicon FinFETs and all other 2D material-based devices, and leading to a smaller delay and much lower energy-delay product than the predicted silicon limit.



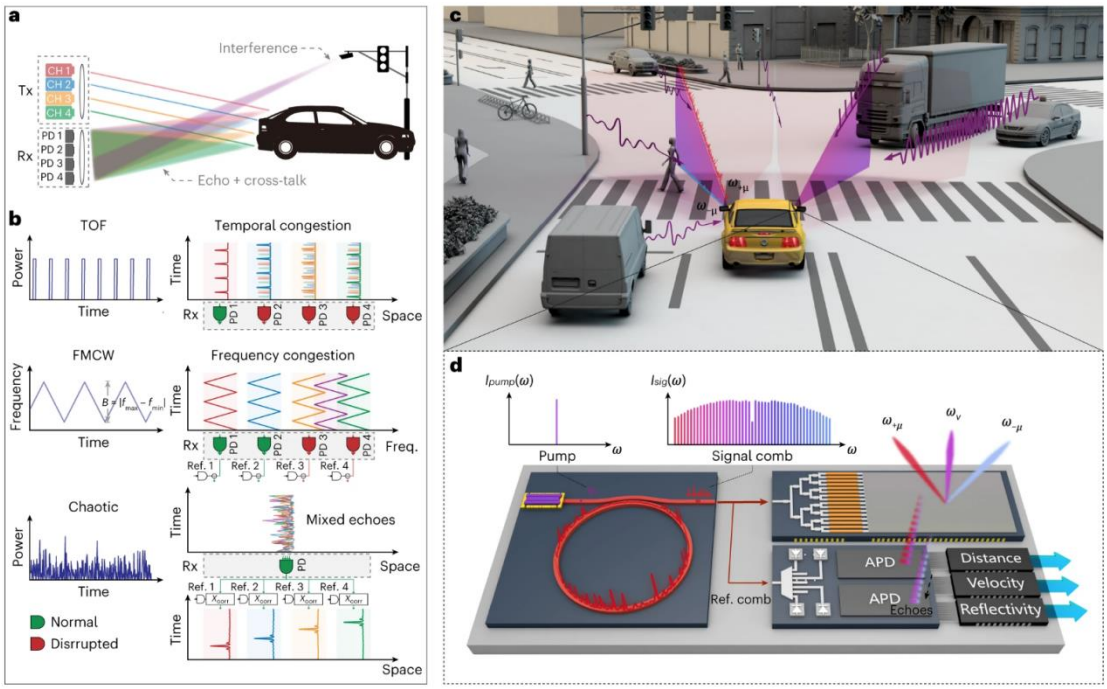
Ballistic two-dimensional InSe transistors. J. Jiang, L. Xu, C. Qiu, L.-M. Peng*. Nature 616，470-475 (2023).*

52．高精度抗干扰并行激光雷达

三维成像系统中的时间-频率阻塞问题长期制约传感技术的发展。**王兴军教授研究组**与合作者提出了一种基于并行混沌熵源的极简硅基片上并行激光雷达架构。该方案展现出的系统简易性和抗干扰能力有望重塑激光雷达技术生态。

Parallel Chaotic Lidar

The temporal and frequency congestion are long term bottleneck in the light detection and ranging. **Prof. Xingjun WANG** and collaborators have developed a chaotic microcomb based parallel lidar. This advancement has the potential to reshape the LiDAR ecosystem, providing a low-cost, efficient, and reliable solution for the next generation of LiDAR technologies.



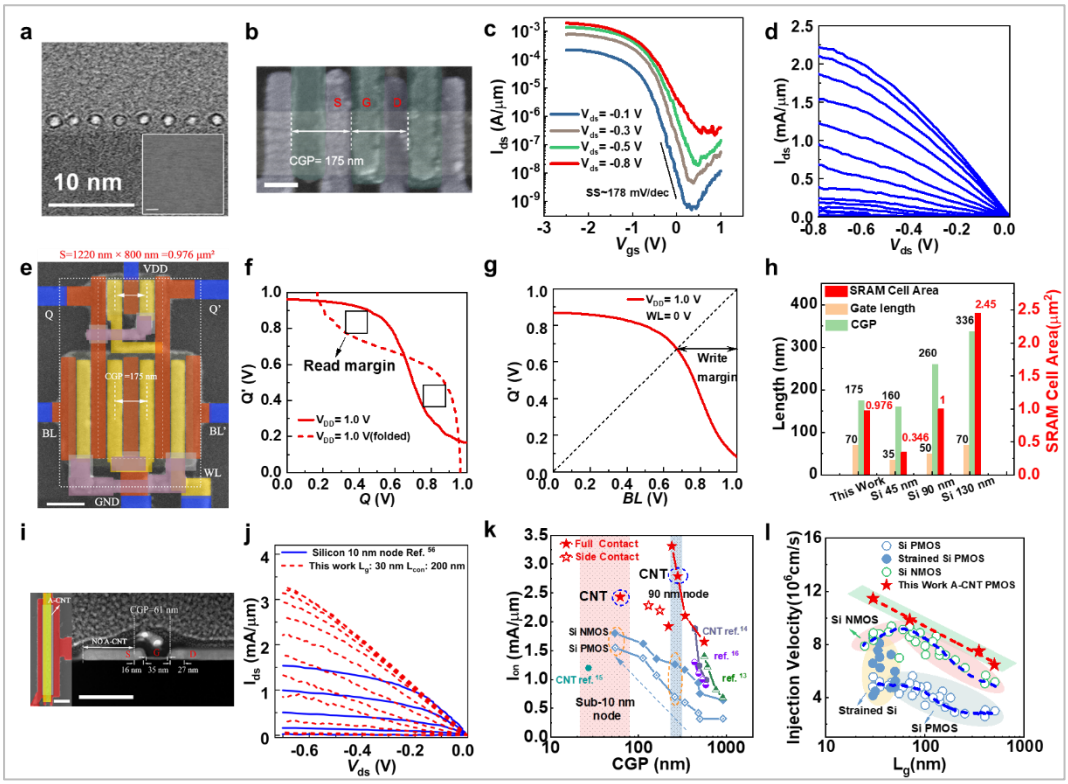
Chen R#, Shu H#, Shen B#, Lin C#, Xie W, Liao W, Tao Z, Bowers J*, Wang X*. Breaking the temporal and frequency congestion of LiDAR by parallel chaos. Nature Photonics, 2023, 17, 306-314.*

53．将碳纳米管器件技术推进至 90 纳米节点

张志勇教授和彭练矛教授联合课题组首次展示了基于阵列碳纳米管的 90 nm 节点晶体管和电路，器件性能超越硅基商用 45 nm 节点。课题组进一步探索了碳基晶体管尺寸缩减的可能性，展示了其在亚 10 nm 节点高性能集成电路中的巨大潜力。

Pushing forward carbon nanotube device technology to 90 nm node

Joint Research Group of **Prof. Zhiyong ZHANG and Lian-Mao PENG** has demonstrated, for the first time, 90 nm node transistors and circuits based on aligned carbon nanotubes (A-CNTs), surpassing the electronic performance of silicon 45 nm node transistors. This group has also explored the possibility of further reducing the size of carbon-based transistors, illustrating the potential of A-CNT FETs for high-performance digital ICs at sub-10 nm nodes.



Scaling aligned carbon nanotube transistors to a sub-10 nm node, Yanxia Lin, Yu Cao, Sujuan Ding, Panpan Zhang, Lin Xu, Chenchen Liu, Qianlan Hu, Chuanhong Jin, Lian-Mao Peng, Zhiyong Zhang, Nature Electronics, volume 6, pages 506–515 (2023).

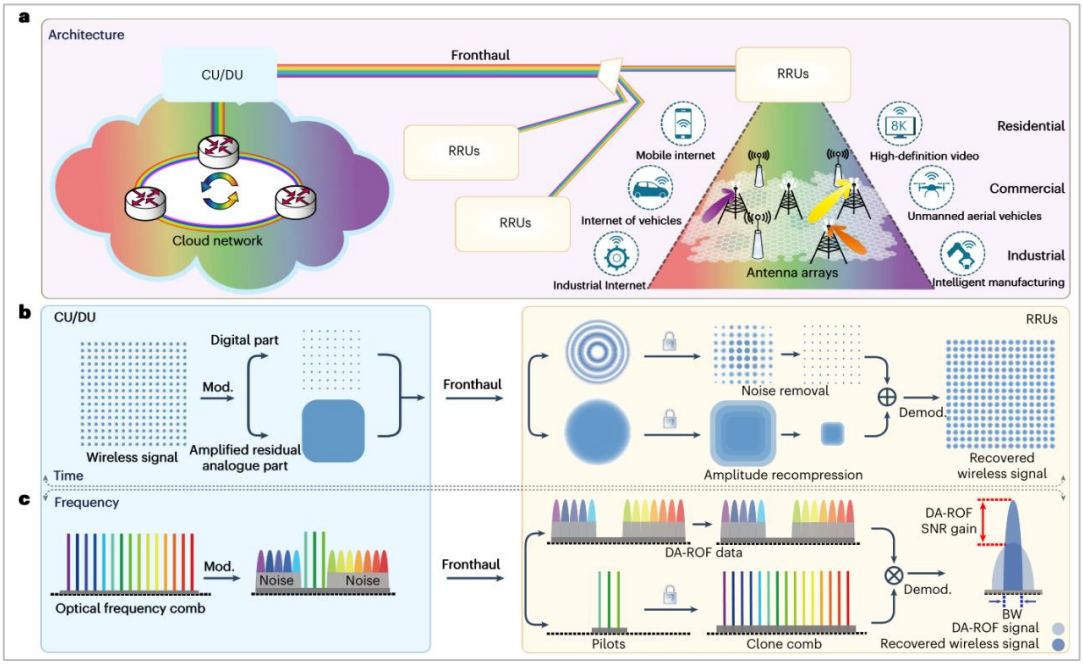
54．面向 6G 通信，克隆光梳赋能大容量高调制格式数字模拟前传

针对 6G 时代无线前传容量和信噪比受限的双重挑战，区域光纤通信网与新型光通信系统国家重点实验室**解晓鹏研究员与合作者**创造性地提出一种基于克隆光梳的数字模拟混合光纤-无线融合前传架构，突破频谱效率-信噪比的约束瓶颈，成功支持超过 5000 个 5G 用户接入和最高达 65536-QAM 的超高制式，同时实现带宽和信噪比两个方面的数量级跃升，位居行业国际领先。

For 6G communications, clone-comb-enabled high-capacity digital-analogue fronthaul with high-order modulation formats

Targeting at the dual challenges of limited capacity and signal-to-noise ratio in 6G fronthaul, the collaborative research teams from the State Key Laboratory of Advanced Optical Communication Systems and Networks have made a pioneering contribution. They have proposed a novel fiber-wireless convergence fronthaul architecture enabled by cloned optical frequency combs and digital-analogue radio-over-fiber technique. This breakthrough surpasses the spectrum efficiency–signal-to-noise ratio constraints, enabling the over 5000 5G users' simultaneous internet access and achieving ultra-high-order modulation formats up to 65536-QAM. These advancements mark a significant leap in both bandwidth and signal-to-noise ratio, positioning it at the forefront of

global techniques in the field.



Clone-comb-enabled high-capacity digital-analogue fronthaul with high-order modulation formats. C. Zhang, Y. Zhu, B. He, J. Lin, R. Liu, Y. Xu, L. Yi, Q. Zhu, W. W. Hu, W. S. Hu, Z. Chen, X. Xie. Nature Photonics 17, 1000-1008 (2023).

计算机学院（School of Computer Science）

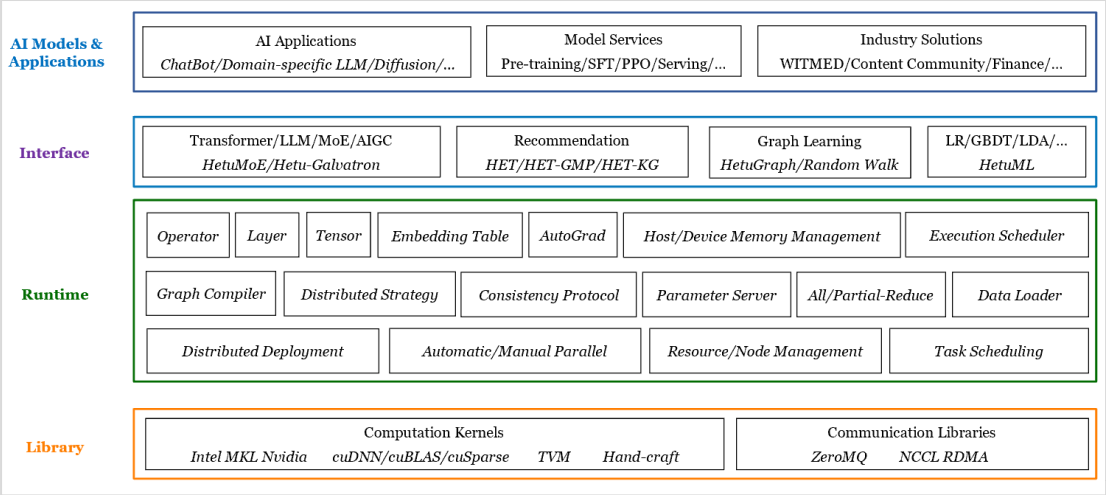
55．易用、高效的大模型基础设施

近期，以 ChatGPT 为代表的基础「大模型」在多种多样的应用场景中都大放异彩，然而，大模型拥有着动辄数百亿、千亿甚至万亿规模的参数量，面临高昂的计算、存储、以及通信开销，也为 AI 基础设施带来了巨大的挑战。针对这一挑战，**崔斌教授团队**基于自主研发的高性能分布式深度学习系统-河图（Hetu），围绕大模型的预训练、精调、推理、部署等全链路功能开展了系统性的优化工作，提出了最优分布式运行策略搜索、细粒度资源管理、资源负载自适应优化等多项关键技术。相关成果不但被录用至 SIGMOD、VLDB、ASPLOS 等国际顶级学术会议，还被应用至腾讯、阿里巴巴、字节跳动等多家企业的大模型训练与推理场景，在千卡千亿参数大模型任务上性能提升高达 80%，有效节省近千万元计算成本。

Easy-to-use and Efficient Infrastructure for Foundation Models

Recently, foundation models represented by ChatGPT have shone in a variety of application scenarios. However, foundation models often have tens of billions, hundreds of billions or even trillions of parameters, and face expensive calculations, storage, and communication cost, posing huge challenges to AI infrastructure. **Prof. Cui BIN**'s team from the School of Computer Science, Peking University, proposed a series of system optimization works for the end-to-end functionalities of foundation models, such as pre-training, fine-tuning,

inference, and deployment. Based on Hetu, a high-performance distributed deep learning system independently developed by the team, numerous key techniques were developed, such as optimal automatic parallelism, fine-grained resource management, and workload adaptive optimization. Relevant results have not only been accepted to top-tier international conferences such as SIGMOD, VLDB, and ASPLOS, but have also been applied to foundation model training and inference scenarios of several enterprises such as Tencent, Alibaba, and ByteDance, improving the performance by up to 80% and saving nearly 10 million yuan in costs.



The system framework of Hetu.

Miao, X., Wang, Y., Jiang, Y., Shi, C., Nie, X., Zhang, H., & Cui, B. Galvatron: Efficient Transformer Training over Multiple GPUs Using Automatic Parallelism. VLDB 2023.

Nie, X., Liu, Y., Fu, F., Xue, J., Jiao, D., Miao, X., ... & Cui, B. Angel-PTM: A Scalable and Economical Large-scale Pre-training System in Tencent. VLDB 2023.

Nie, X., Miao, X., Wang, Z., Yang, Z., Xue, J., Ma, L., ... & Cui, B. FlexMoE: Scaling Large-scale Sparse Pre-trained Model Training via Dynamic Device Placement. SIGMOD 2023.

Miao, X., Shi, C., Duan, J., Xi, X., Lin, D., Cui, B., & Jia, Z. SpotServe: Serving Generative Large Language Models on Preemptible Instances. ASPLOS 2024.

Jiang, Y., Fu, F., Miao, X., Nie, X., & Cui, B. Osdp: Optimal sharded data parallel for distributed deep learning. IJCAI 2023.

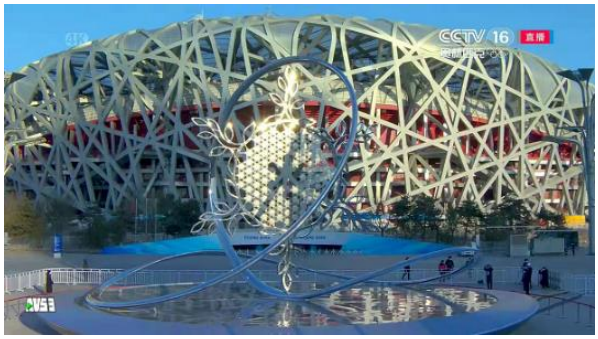
Miao, X., Nie, X., Zhang, H., Zhao, T., & Cui, B. Hetu: A highly efficient automatic parallel distributed deep learning system. SCIS 2023.

56．AVS3 8K 超高清标准保障 8K 超高清频道开播

马思伟教授团队主持制定了面向 8K 超高清的 AVS3 视频编码标准，被采纳为广电行业标准，被国际 DVB 和 ETSI 标准采纳。该团队开发了 AVS3 8K 超高清编解码系统，支撑了中央电视台开播 CCTV-8K 超高清频道，2022 年北京冬奥会期间，CCTV-8K 超高清频道完成开闭幕式直播与各类赛事节目直播 35 场。

AVS3 8k UHD Video Coding Standard for 8K UHDTV Channel

Prof. Siwei MA and his team led the development of AVS3 video compression standard, for 8K Ultra-high Definition (UHD) contents, which was been adopted as the Industry Standards standard for television broadcasting, also been adopted by DVB and ETSI, as international standard. This team also developed the AVS3 8K encoding and decoding systems for CCTV (China Central TV Station) to launch 8K channel. During the Beijing Winter Olympics in 2022, there were 35 events that have been broadcasted in CCTV-8K channel, including opening/closing ceremony and other games.



57．VR 技术赋能沉浸式视频体验

马思伟教授团队构建了沉浸式视频全链路技术体系，提出了虚拟视点合成技术、三维视频高效编码与实时重建方法，研发了端到端交互式低延迟 VR 直播系统，最高可以带宽节省 75%，显著提升了奥运/亚运赛事多维度观赛体验。该系统也将为未来高水平赛事转播标准的建立提供重要参考，应用于 2022 北京冬奥、2023 杭州亚运赛事播出。

VR Technology Enables Immersive Video Experience

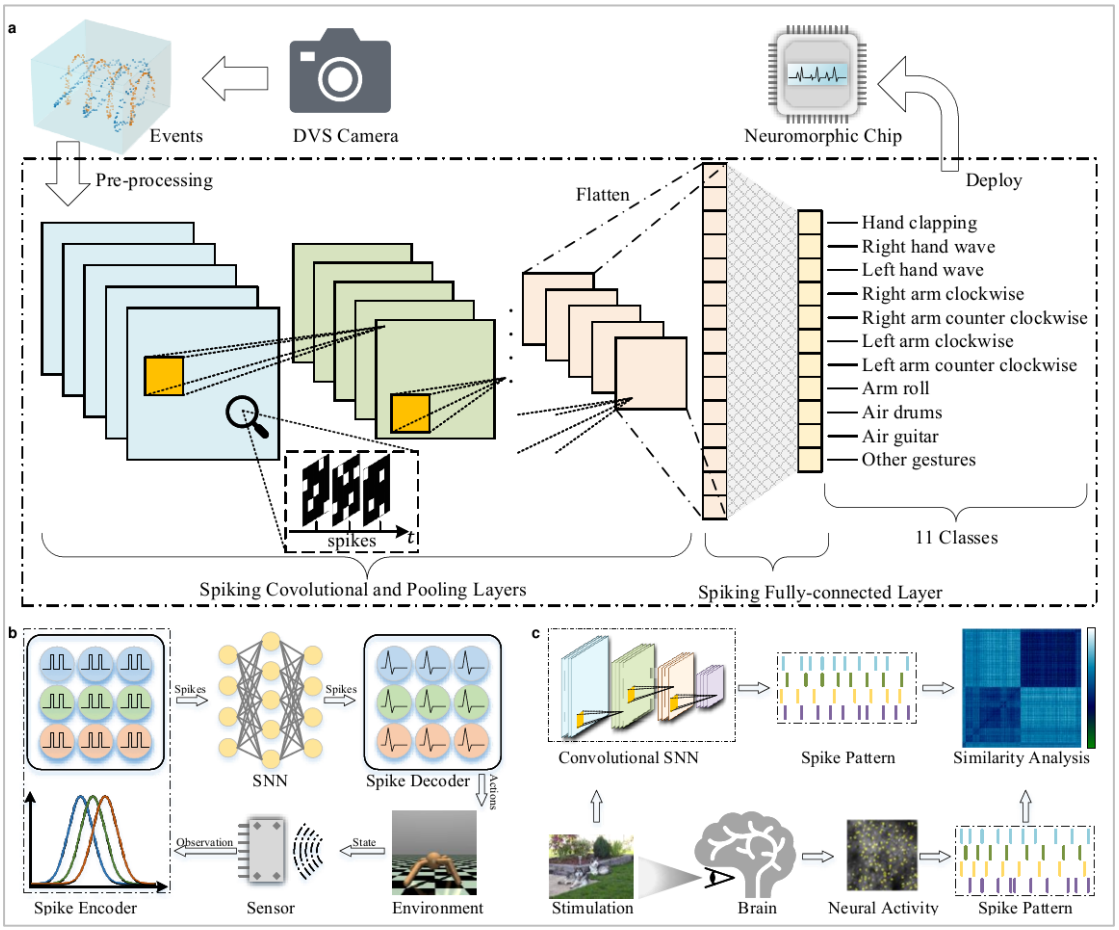
Professor Siwei MA and his team built an immersive video full-link technology system, proposed virtual viewpoint synthesis technology, efficient 3D video encoding and real-time reconstruction methods, and developed an end-to-end interactive low-latency VR live broadcast system, which can save up to 75% of bandwidth. Significantly improves the multi-dimensional viewing experience of Olympic/Asian Games events. This system will also provide an important reference for the establishment of high-level event broadcast standards in the future, and has been employed in the video broadcast of the 2022 Beijing Winter Olympics and the 2023 Hangzhou Asian Games.

58．开源脉冲神经网络深度学习框架发布

脉冲神经网络在神经形态计算芯片上拥有百倍于传统神经网络的能耗优势，但搭建和训练深度脉冲神经网络的工具框架尚不成熟。田永鸿教授团队构建并开源了国际上首批脉冲神经网络深度学习框架之一的惊蛰框架，拥有最高的计算性能和全栈式的解决方案，一经推出就受到了研究者们的持续关注，在 GitHub 有近 1000 的星标数、超过 130 篇论文使用该框架，将神经形态计算的应用边界不断扩展。

Release of the open-sourced Deep Learning Framework for the Spiking Neural Networks

Spiking Neural Networks (SNNs) have 100x energy efficiency on neuromorphic chips than that of the traditional neural networks. However, there is no mature framework available for building and training deep SNNs. **Prof. Yonghong TIAN** and his team present an open-source SpikingJelly, which is one of the first frameworks for spiking deep learning. SpikingJelly provides the highest simulation performance and full-stack solutions for deep SNNs. SpikingJelly attracts much interest with about 1000 stars on GitHub and is widely adopted by researchers by more than 130 publications, as well as extends the boundaries of neuromorphic computing.



Fang, Wei, Yanqi Chen, Jianhao Ding, Zhaofei Yu, Timothée Masquelier, Ding Chen, Liwei Huang, Huihui Zhou, Guoqi Li, and Yonghong Tian. "SpikingJelly: An open-source machine learning infrastructure platform for spike-based intelligence." Science Advances 9, no. 40 (2023): eadi1480.

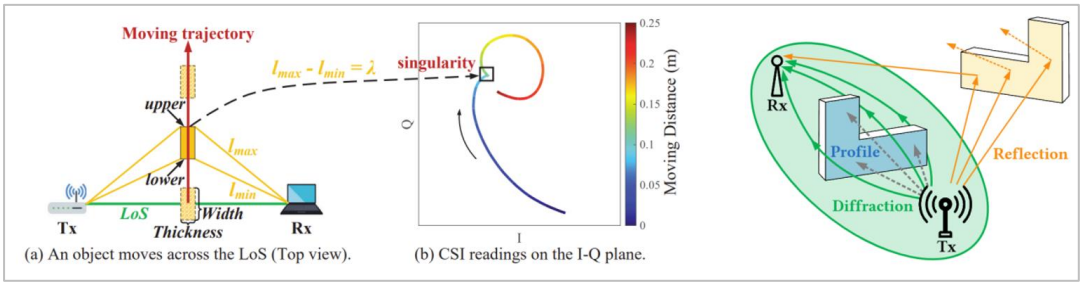
59．揭示高精度无线测量物体尺寸、形状的原理

现有无线感知理论认为对物体尺寸、形状进行准确测量、成像需要采用大带宽、多天线的无线系统，而利用窄带的无线信号如 Wi-Fi 是无法做到的。**张大庆教授团队**通过完整建模无线信号的衍射效应，提出了使用窄带 Wi-Fi 信号高精度测量物体尺寸、形状的新方法。通过精确建模物体在不同位置下无线信道与物体尺寸、形状的关系，团队利用商用 Wi-Fi 设备首次实现了毫米级精度的一维尺寸测量和二维形状成像，为无线感知领域带来了原创的理论、全新的应用和扩展的感知能力。

Revealing the principle of high-precision wireless measurement of object size and shape, expanding the sensing capability of wireless signals

Existing wireless sensing theory indicates that accurate measurement of object size and shape require the use of large-bandwidth, multi-antenna wireless

systems, which cannot be achieved using narrow-band wireless signals such as Wi-Fi. By modeling the diffraction effect of wireless signals, **Prof. Daqing ZHANG**'s team from the School of Computer Science at Peking University proposed a new method for using narrowband Wi-Fi signals to measure the size and shape of objects with high precision. By accurately modeling the relationship between wireless channels and object size and shape at different locations, the team used commercial Wi-Fi devices to achieve millimeter-level precision size measurement and shape imaging for the first time, bringing new theory, innovative applications and expanded sensing capability to the wireless sensing field.



(a) An object moves across the LoS (Top view). (b) CSI readings on the I-Q plane.

Xuanzhi Wang, Kai Niu, Anlan Yu, Jie Xiong, Zhiyun Yao, Junzhe Wang, Wenwei Li, and Daqing Zhang. 2023. WiMeasure: Millimeter-Level Object Size Measurement with Commodity WiFi Devices. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 7, 2, Article 79 (June 2023), 26 pages.

60．数联网基础软件

针对畅通数据资源大循环的数字经济与数字社会发展重大需求，**黄罡教授团队**通过揭示数据场景化使用的数据语用机理，发明了基于数字对象语用复杂网络（数联网）的数据空间构造方法，研制并开源了数联网地址系统、语用系统及调度系统，入选 BenchCouncil（国际测试委员会）2023 年度世界开源贡献榜 Open100，北大共建的新型研发机构获批数据空间技术与系统全国重点实验室（黄罡教授任实验室主任），有力支撑了中国工业互联网数据要素登记（确权）平台、北京市“数据二十条”的可信数据基础设施、上海数据交易所全国一体化数据要素流通交易、北京大兴和上海临港数据跨境等重要行业与区域数字中国建设重大任务的实施。

Basic Software of Internet of Data

Aiming at the key demands for the development of the digital economy and digital society by smoothing data circulation system, **Prof. Gang HUANG** and his research team invented the data space construction method based on the complex network of digital object pragmatics (i.e., Internet of Data, IoD) by revealing the data pragmatic mechanism of situational data usage. They have developed and open-sourced several basic software of IoD, including the address system, pragmatic system, and scheduling system, which were selected as 2023 TOP 100 Open Source Achievement Award presented by

International Open Benchmark Council (BenchCouncil). In 2023, based on the new R&D institution co-founded by Peking University, the National Key Laboratory of Data Space Technology and System was approved with Prof. Gang HUANG as the laboratory director. The basic Software of IoD has provided strong support for the implementation of Digital China Strategy on important industries and regions, such as the registration (right confirmation) platform for data elements of China's Industrial Internet, the trustworthy data infrastructure for Beijing's "Twenty Measures of Data Development", the nationwide integrated data element circulation and transaction at the Shanghai Data Exchange, and the cross-border data exchange in Beijing Daxing and Shanghai Lingang.

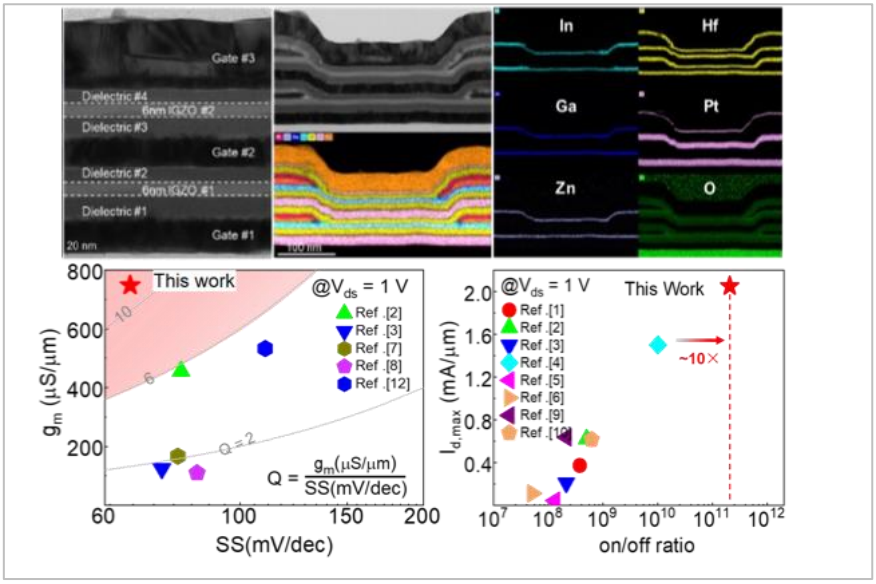
集成电路学院（School Of Integrated Circuits）

61．国际首个氧化物半导体堆叠围栅纳米片器件

高性能氧化物半导体在三维集成架构中的后道逻辑与存储方面具有重要应用价值。**吴燕庆研究员-黄如院士团队**突破了超薄氧化物半导体沟道的界面稳定性瓶颈，首次在国际上实现了超薄氧化物半导体堆叠围栅纳米片器件，短沟道器件的品质因数（跨导与亚阈斜率比）与器件开关比分别大幅提升至同类器件最高水平的两倍与十倍，为我国具有自主知识产权的新型集成电路器件奠定了重要基础。

First Demonstration of Sequential Integration for Stacked Gate-All-Around a-IGZO Nanosheet Transistor

High-performance stacked gate-all-around (GAA) a-IGZO 2-layer nanosheets field-effect transistors (NSFET) has been demonstrated for the first time, with the entire thermal budget below 300^{o}C with back-end-of-line (BEOL) compatibility. The short channel 50 nm-long transistor exhibits a record-high g_m of 1.13 mS/μm at V_{ds} =1.5 V and record-high on-state current of 2.05 mA/μm at V_{ds} =1 V, the highest among all IGZO-based FETs. Meanwhile, the same short channel transistor achieves ultra-low SS of 66 mV/dec, realizing a record-high quality factor gm/SS larger than 10 for the first time among a-IGZO transistors.



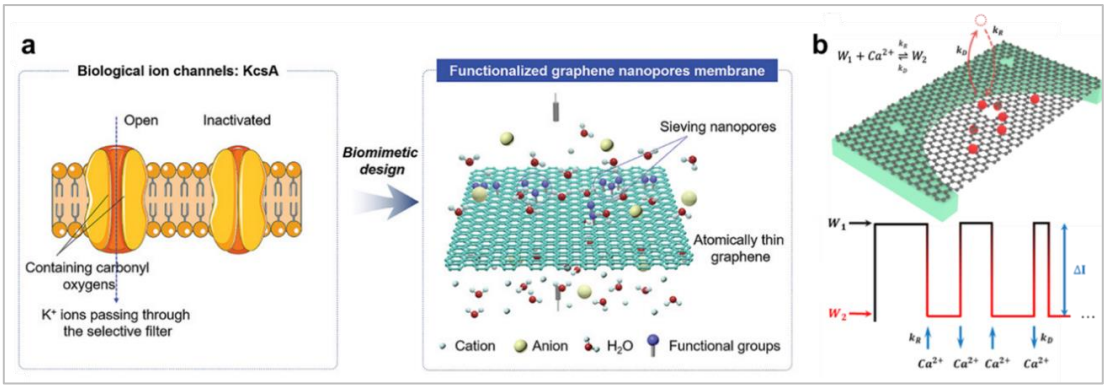
Qijun Li, Wenjie Zhao, Qianlan Hu, Chengru Gu, Shenwu Zhu, Honggang Liu, Ru Huang, Yanqing Wu, First Demonstration of Sequential Integration for Stacked Gate-All-Around a-IGZO Nanosheet Transistors with Record I_d = 2.05 mA/μm, g_m = 1.13 mS/μm and Ultralow SS = 66 mV/dec. IEEE International Devices Meeting (IEDM), 37.4.1-37.4.4，2023.*

62．零维限域空间离子输运研究

研究（亚）纳米零维限域空间内离子输运过程对探索极端限域内纳流体输运新机制和促进其在传感、检测、分离等领域的应用发展至关重要。**王路达研究员课题组**以原子级薄的石墨烯为原型材料，利用微纳加工技术，创新地发展了一系列石墨烯零维限域空间物理结构设计和化学微环境协同调控的策略，实现了零维限域空间对多种阴阳离子输运特性的调控，并探索了离子跨通道输运的噪声机制。该研究深入地理解了（亚）纳米零维限域下离子的行为及输运机理，为面向传感、分离、能源领域构建新型高性能纳米孔离子器件提供了新的思路。

The investigation of ionic transport in zero-dimensional confined spaces

Investigating ionic transport in sub-nanometer zero-dimensional (0D) confined spaces is crucial for exploring novel mechanisms of nanofluidic transport and promoting applications in sensing, detection, and separation. **Prof. Luda WANG**'s group develops a series of strategies for constructing 0D confined spaces in atomically thin graphene by synergistically designing physical structure and chemical micro-environment. They achieved control of various ions' transport in 0D confined spaces, and explored the noise mechanism in ionic transport across channels. This study deepens the understanding of transport mechanisms in sub-nanometer nanopores, and provides new ideas for constructing nanopore devices for sensing, separation, and energy harvesting.



Covalently Functionalized Nanopores for Highly Selective Separation of Monovalent Ions. L. Guo, Y. Liu, H. Zeng, S. Zhang, R. Song, J. Yang, X. Han, Y. Wang, ***L. Wang****, Advanced Materials 2023, 2307242.*

Low-frequency flicker noise in stochastic ionic transport across atomically thin graphene nanopores. R. Song, H. Zeng, S. Zhang, Y. Wang, X. Han, X. Chen, ***L. Wang****, Cell Reports Physical Science 2023, 4 (1), 101210.*

Preanchoring Enabled Directional Modification of Atomically Thin Membrane for High-Performance Osmotic Energy Generation. Y. Liu, S. Zhang, R. Song, H. Zeng, ***L. Wang****, Nano Letters 2023, accepted.*

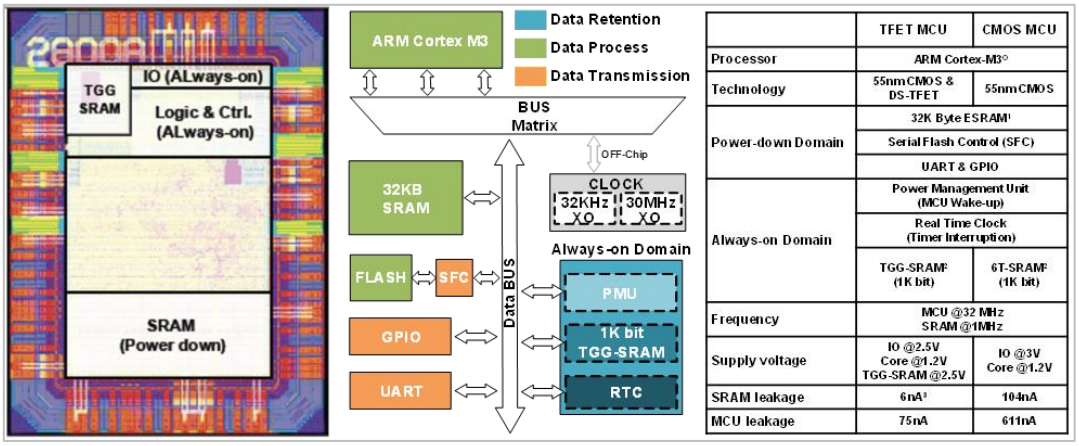
63．世界首个基于新型隧穿晶体管的大规模集成技术及其极低功耗电路芯片

集成电路已进入后摩尔时代，晶体管和电路芯片的功耗问题是制约其未来发展的一大瓶颈，降低功耗、提升性能功耗比正成为国际上后摩尔时代集成电路技术发展的新驱动力。**黄如院士-黄芊芊研究员**团队致力于从芯片最核心的器件层面解决芯片功耗的瓶颈问题，与国内领先的集成电路制造企业（中芯国际）和创新平台等合作研发了世界上首个基于 12 英寸 CMOS 大生产线的超低功耗互补隧穿晶体管集成技术，在同一硅晶圆片上同时实现了性能优异的新型隧穿器件和标准 CMOS 器件的制备，晶体管电流开关比达到了同类器件的业界国际领先水平，并成功研制出世界上首个基于隧穿晶体管的极低功耗微处理器芯片，有望从集成电路最核心的晶体管层面解决现行 CMOS 电路芯片的功耗瓶颈问题，为具有我国自主知识产权的超低功耗集成电路技术和产业发展奠定了重要基础。

A Sub-100nA Ultra-low Leakage MCU Embedding Always-on Domain Hybrid Tunnel FET-CMOS on 300mm Foundry Platform

This work firstly demonstrates an ultra-low leakage microcontroller unit (MCU) based on 55nm tunnel FET (TFET)-CMOS hybrid 300mm foundry platform. By utilizing the large on-state current and record high on-offf current ratio of the dopant segregation TFET (DS-TFET), a 1Kbit TFET-Gated-Ground static random access memory (TGG-SRAM) is implemented in MCU always-on

domain. A voltage-stacking scheme is proposed to regulate the supply voltage. Experimental results show that TGG-SRAM and TFET-MCU obtain order of magnitude standby power reduction, cost 6nA (data retention) and 75nA (deep-sleep mode) leakage current respectively, indicating the great potential of the TFET-CMOS hybrid platform for cutting-edge power-dieting MCU.



	TFET MCU	CMOS MCU
Processor	ARM Cortex-M3©	
Technology	55nm CMOS & DS-TFET	55nm CMOS
Power-down Domain	32K Byte ESRAM[1]	
	Serial Flash Control (SFC)	
	UART & GPIO	
Always-on Domain	Power Management Unit (MCU Wake-up)	
	Real Time Clock (Timer Interruption)	
	TGG-SRAM[2] (1K bit)	6T-SRAM[2] (1K bit)
Frequency	MCU @32 MHz SRAM @1MHz	
Supply voltage	IO @2.5V Core @1.2V TGG-SRAM @2.5V	IO @3V Core @1.2V
SRAM leakage	6nA[3]	104nA
MCU leakage	75nA	611nA

A Sub-100nA Ultra-low Leakage MCU Embedding Always-on Domain Hybrid Tunnel FET-CMOS on 300mm Foundry Platform. Yaoru Hou#, Kaifeng Wang#, Chenxing Liu-Sun, Jianfeng Hang, Xinfang Tong, Chunyu Peng, Yongqin Wu, Ye Ren, Weihai Bu, Xin Si, Bo Liu, Xiulong Wu, Jun Yang, Hao Cai, Qianqian Huang*, Ru Huang. in IEDM Tech. Dig., pp. 35.7.1-35.7.4, 2023.*

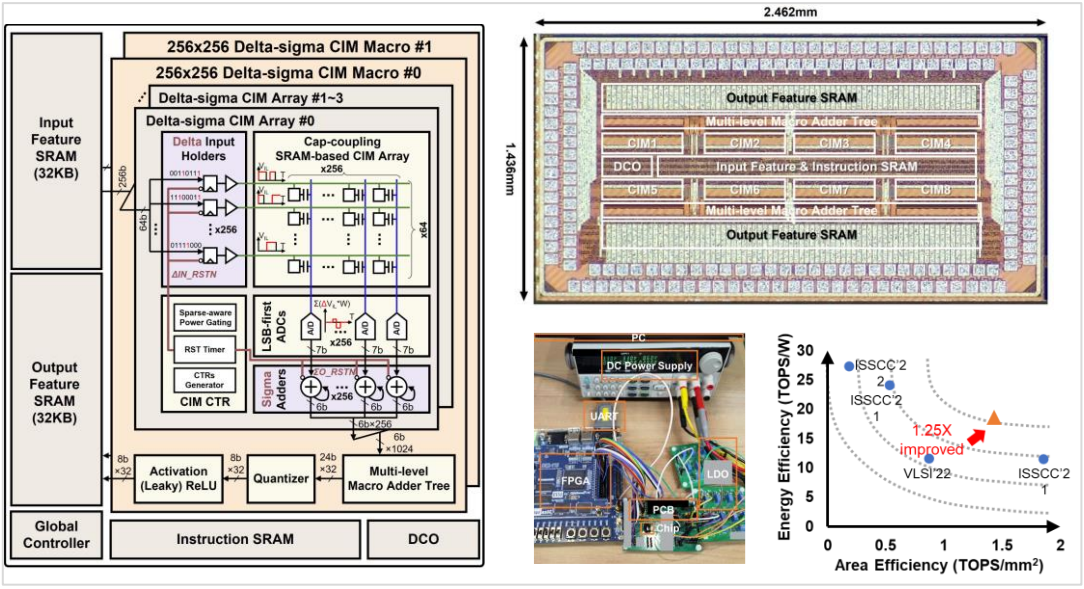
64．突破算力瓶颈的 SRAM 存算一体 AI 芯片

人工智能时代对于芯片的算力能效和算力密度提出了极高要求。**黄如院士-叶乐教授团队**长期深耕存算一体技术路线，其研制的新型 SRAM 存算一体技术发表于“芯片设计奥林匹克会议”ISSCC 2023 并超越世界先进水平 1.25 倍，为大语言模型、图网络、视觉处理等人工智能应用提供了高算力密度芯片基础。团队长期研究基于 SRAM 存算一体技术，在国产工艺下实现先进工艺节点的计算能效和密度，旨在打造突破美国 1017 芯片禁运算力密度红线的可行技术路径。

The Breakthrough in Computing Bottleneck by SRAM Compute-in-Memory AI Chip

The era of artificial intelligence imposes extremely high demands on chip energy efficiency and area efficiency. Professor Huang Ru and Professor Ye Le, from the Institute of Integrated Circuits, have been devoted to the development of computing-in-memory (CIM) for many years. Their newly developed SRAM-based CIM integrated chip has surpassed the world state-of-the-art design by 1.25× and presented at the "Chip Olympics" conference ISSCC 2023. This technique holds the potential to provide high energy and area efficiency chip solutions in various AI application, such as large language model, graph network and visual processing. The research team has dedicated in SRAM-based CIM development and achieves advanced computing performance using

domestic processes. This lays a foundation for breaking through the area efficiency redline of the U.S. chip export control updated on October 17, 2023.



A 22nm Delta-Sigma Computing-In-Memory (Δ∑CIM) SRAM Macro with Near-Zero-Mean Outputs and LSB-First ADCs Achieving 21.38TOPS/W for 8b-MAC Edge AI Processing. Peiyu Chen, Meng Wu, Wentao Zhao, Jiajia Cui, Zhixuan Wang, Yadong Zhang, Qijun Wang, Jiayoon Ru, Linxiao Shen, Tianyu Jia, Yufei Ma, Le Ye, Ru Huang, 2023 IEEE International Solid-State Circuits Conference (ISSCC), San Francisco, CA, USA, 2023, pp. 140-142

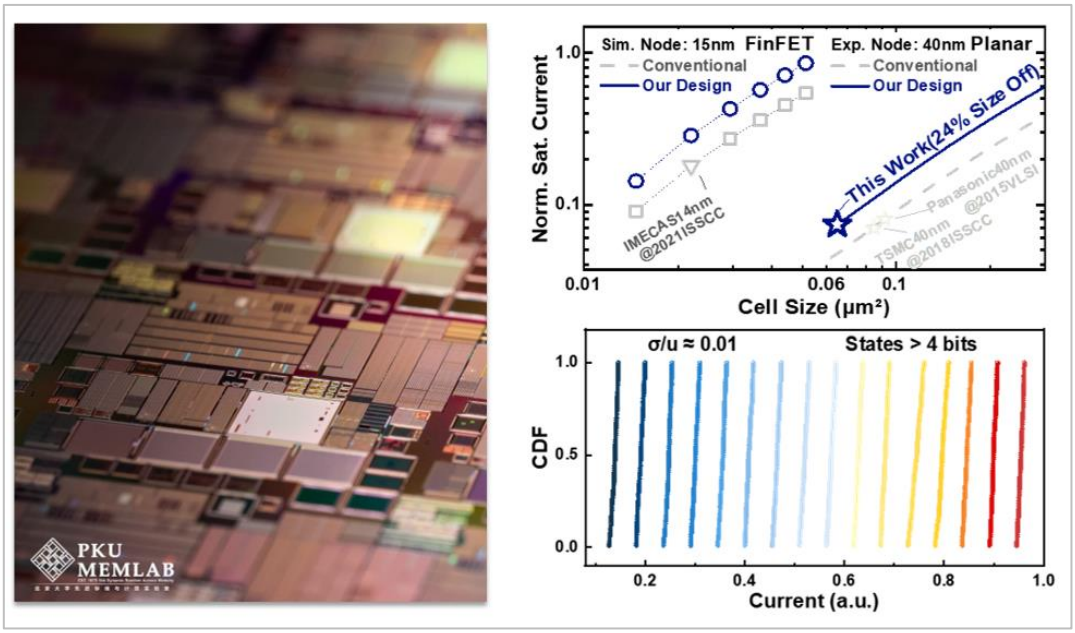
65．突破新型阻变存储器密度极限

高密度与高可靠性是下一代半导体存储器的核心要求。**黄如院士、蔡一茂教授、王宗巍助理研究员**与研究团队首次在商用 40nm CMOS 大生产线上研发出超高密度动态栅(Dynamic Gate) 阻变存储器技术，创造了新型阻变存储器集成密度的世界纪录（15.43 Mb/mm^2）。团队基于该技术研制的阻变存储器芯片实现了多值数据存储（≥4 bit/单元）以及极限温度下的超长数据保持时间（150℃下超过 10 年），在工业级存储应用领域展现出巨大潜力。

Breaking the Density Limit of Emerging Resistive Memory

High density and high reliability are critical requirements for next-generation semiconductor memory. For the first time, **Prof. Ru HUANG, Prof. Yimao CAI, and Dr. Zongwei WANG** and their research team demonstrate the dynamic gate resistance random access memory (ReRAM) technology based on commercial 40nm CMOS platform, achieving a world record for the integration density of the ReRAM (15.43 Mb/mm^2). The ReRAM chip developed by the team based on dynamic gate technology achieves multi-level data storage (≥4 bit/cell) and ultra-long data retention time at extreme temperatures (more than

10 years at 150°C), showing great potentials in industrial-grade storage applications.



Qishen Wang, Yuhang Yang, Zongwei Wang, Shengyu Bao, Jingwei Sun, Linbo Shan, Lin Bao, Yi Gao, Haisu Zhang, Yaotian Ling, Wuzhi Zhang, Yansheng Wang, Yimao Cai, Ru huang, A Logic-Process Compatible RRAM with 15.43 Mb/mm2 Density and 10 years@150°C retention using STI-less Dynamic-Gate and Self-Passivation Sidewall, IEEE International Electron Devices Meeting (IEDM), San Francisco CA, USA, 2023.

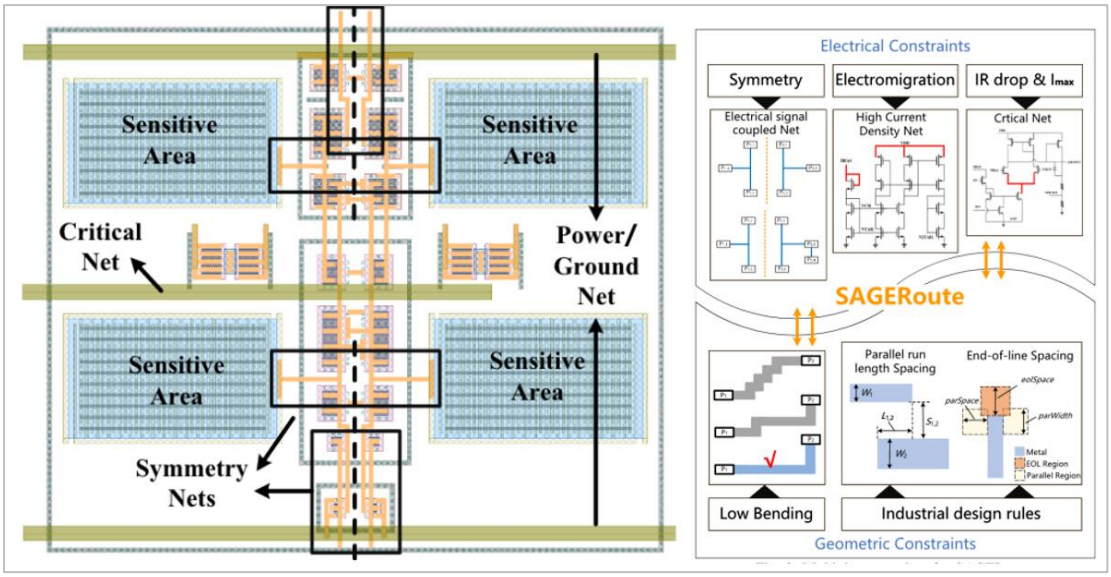
66．为模拟集成电路设计插上“翅膀”

版图设计是当前模拟集成电路设计（以下简称模拟电路）的主要效率瓶颈之一。其中，布线对模拟电路版图的性能至关重要，而布线设计空间的复杂性阻碍了模拟电路版图自动化技术的进一步发展。**林亦波研究员和王润声教授**团队开发了一个协同模拟布线框架 SAGERoute。该框架通过全面系统地考虑各类约束条件，有效地缩小设计空间，从而得到高质量的布线结果。这项工作大幅提升了模拟电路设计的效率。相关成果获得 DATE 2023 年度最佳论文奖，并集成到概伦电子公司的商业工具中。

Synergistic analog routing towards silicon-proven applications

Layout design is extremely time-consuming in current analog intergrated circuit (IC) design flow. Routing is critical to the performance of analog IC layouts, while the complicated design space in routing hinders further development of analog layout automation. Prof. Yibo Lin and Prof. Runsheng Wang from the School of Integrated Circuits propose a synergistic analog routing framework (SAGERoute). SAGERoute can effectively shrink the routing design space through holistic and systematic consideration of various constraints, which can

dramatically speeds up analog IC design closure. This work has been integrated into the commercial tool from PRIMARIUS and received the Best Paper Award from DATE 2023.



SAGERoute: Synergistic Analog Routing Considering Geometric and Electrical Constraints with Manual Design Compatibility. H. Zhang, X. Gao, H. Luo, J. Song, X. Tang, J. Liu, Y. Lin, R. Wang, R. Huang. Design, Automation & Test in Europe Conference & Exhibition (DATE), 2023, Best Paper Award.

智能学院（School of Intelligence Science and Technology）

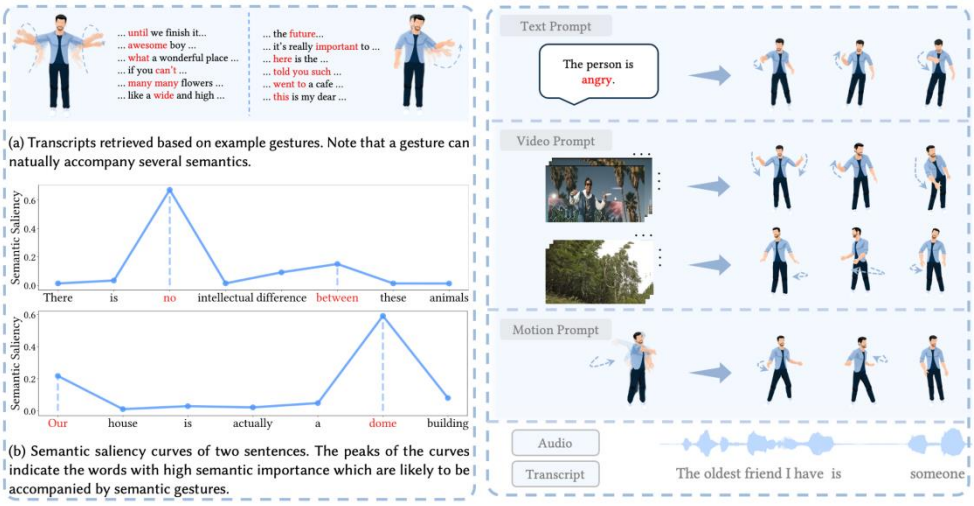
67．拟真共语手势让数字人“活”起来

根据音频/文本生成拟真的手势动作是一个存在三十年的心理语言学与计算机图形学交叉热点问题。**刘利斌助理教授团队**开创性地提出了通过大规模多模态预训练模型对齐解决“文本、视频、三维动作”三模态的语义一致性问题，实现了落地级的数字人肢体动作风格控制能力。该系统获 2023 年度计算机图形学顶级会议 SIGGRAPH 最佳论文荣誉提名，为研究人类不同形态手势的发生机理与仿真、业内数字人产品落地提供了新的思路。

Realistic Co-Speech Gestures Bring Digital Humans to Life

The synthesis of realistic human body gestures based on audio/text input has been a hot interdisciplinary topic for about thirty years, intersecting psycholinguistics and computer graphics. A team led by **Libin LIU** has innovatively proposed a system that achieves semantic aligment among the three modalities of text, video, and 3D motion by aligning them through a large-scale multimodal pretrained model, creating production-level control over the body movements of digital humans. This system was honored with a Best

Paper Honorable Mention Award at the top-tier computer graphics conference, SIGGRAPH 2023. The system provides new insights into researching the mechanisms and simulations of different human gesture forms and the implementation of digital human products in the industry.



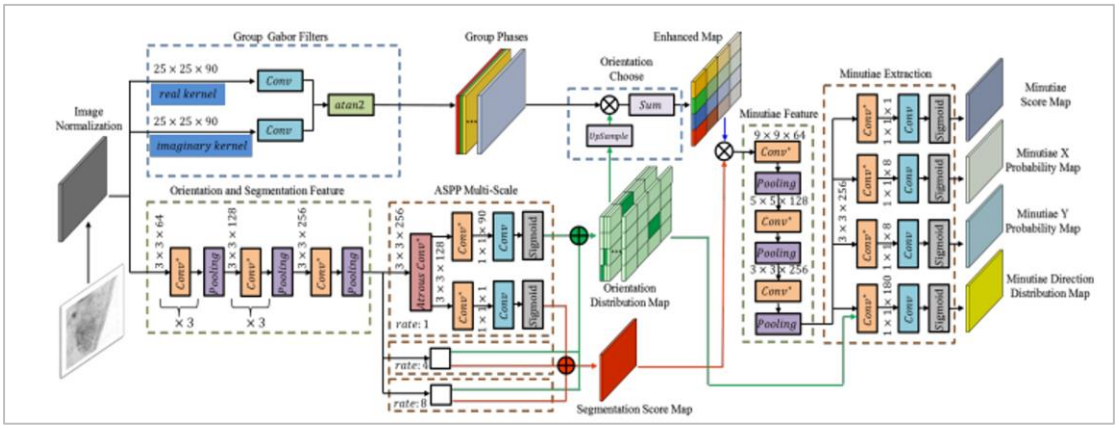
Tenglong Ao, Zeyi Zhang, and Libin Liu. 2023. GestureDiffuCLIP: Gesture Diffusion Model with CLIP Latents. ACM Trans. Graph. 42, 4, Article 42 (August 2023), 18 pages. https://doi.org/10.1145/3592097

68．AI 指纹自动识别

现场指纹自动全自动识别是长期以来的未解决问题。**封举富教授团队**在在国际上首先提出了一种统一的指纹细节点特征提取网络 FingerNet，实现了现场指纹全自动快速识别。目前已在全国多省市推广应用，破获了一大批命案要案。北大团队助力破获特大命案积案的事迹被《人民日报》、《科技日报》等主流媒体报道，产生了广泛的社会影响。

AI fingerprint automated Identification

Fully automated latent fingerprint identification has always been an open problem for a long time. **Prof. Jufu Feng** and his team was the first to propose a unified fingerprint minutiae extraction network, FingerNet, achieving fully automated and fast Latent fingerprint identification. Currently, it has been applied in multiple provinces and cities in China, and a large number of homicide and major cases have been solved. The achievements of the Peking University team in helping to solve the backlog of major homicide cases have been reported by mainstream media such as People's Daily and Science and Technology Daily, and have had a wide social impact.



69．图神经网络新进展

王立威、贺笛团队以图论基本性质作为切入点，发现主流神经网络存在重大缺陷。团队提出了一种简单高效的新型图神经网络解决这一关键问题。该成果在近 5000 篇投稿中脱颖而出，荣获 2023 年机器学习旗舰国际会议 ICLR 杰出论文奖。

A Deeper Understanding of Graph Neural Networks

Using basic properties in graph theory as a starting point, the research team led by Liwei Wang and Di He discovered significant limitations in mainstream graph neural networks. The team then proposed a simple and efficient network architecture to address this critical issue. This achievement stood out among nearly 5000 submissions and was honored with the Outstanding Paper Award at the international machine learning conference ICLR 2023.

Bohang Zhang, Shengjie Luo, Liwei Wang, and Di He. Rethinking the expressive power of gnns via graph biconnectivity.

工学院（Colleague of Engineering）

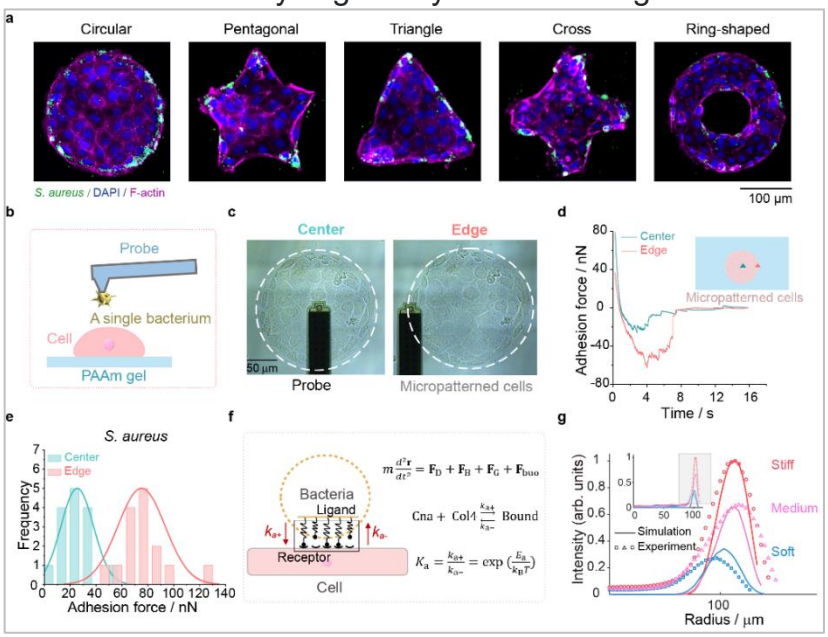
70．揭示空间几何约束诱导细菌-宿主细胞互作的力学生物学机制

空间几何约束等物理力学微环境对于细菌和宿主细胞的功能和行为起着至

关重要的调控作用。**黄建永研究员课题组**基于单细胞力谱技术定量表征了细菌与宿主细胞间的特异性粘附力，建立了细菌与宿主细胞单层相互作用的力-化学耦合模型，揭示了空间几何约束诱导细菌与宿主细胞异质性粘附的时空动态规律及其力学生物学机制，识别了 IV 型胶原在其中的关键调控作用，从力学生物学视角为抗生素辅剂的筛选和临床上改善细菌抗生素治疗方案提供了新的思路和策略。

Mechanobiological mechanism of geometric constraints-dominated bacterial-host interactions

Mechanical microenvironments (*e.g.*, spatially geometric constraints) play a crucial role in regulating the functions and behaviors of bacteria and host cells. **Jianyong HUANG**'s team quantitatively characterizes specific adhesion forces between bacteria and host cells based on single-cell force spectroscopy, establishes a mechanochemical coupling model that reveals spatiotemporal dynamics of heterogeneous adhesion between bacteria and host cells under spatially geometrical constraints and the underlying mechanobiological mechanism, and thus identifies the key regulatory role of collagen IV in the process of bacterial-host interactions. This work provides new ideas and strategies for screening of antibiotic adjuvants and clinical improvement of bacterial antibiotic therapy from the perspective of mechanobiology.



Geometric constraint-triggered collagen expression mediates bacterial-host adhesion. Y. Feng, S. Wang, X. Liu, Y. Han, H. Xu, X. Duan, W. Xie, Z. Tian, Z. Yuan, Z. Wan, L. Xu, S. Qin, K. He, J. Huang. Nature Communications 14, 8165 (2023).*

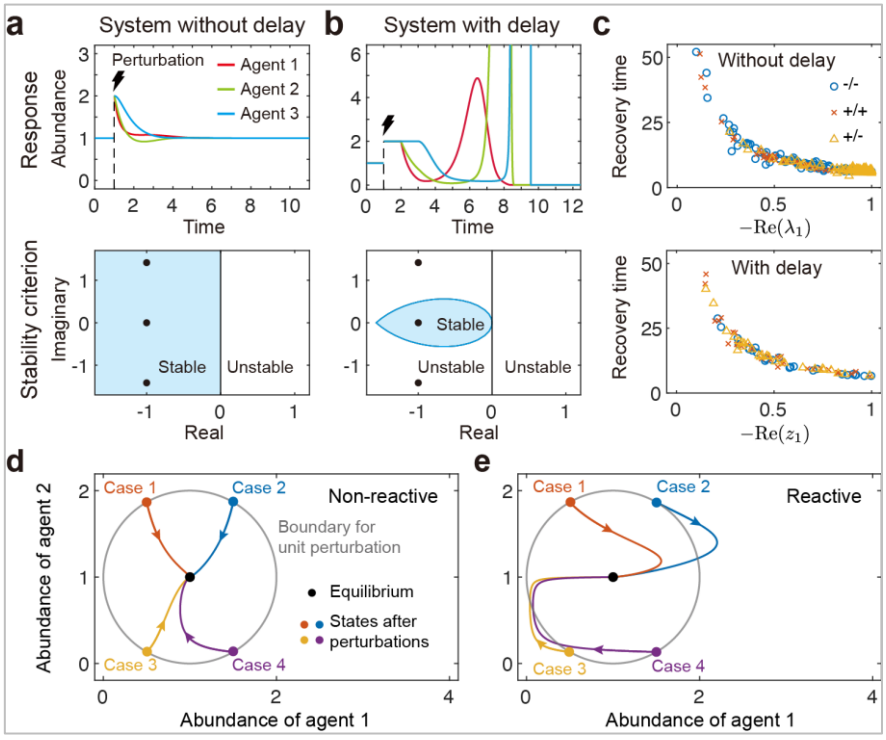
71．深入理解复杂系统的动力学行为

理解复杂系统的稳定性，即系统是否能从外界扰动中恢复，是多学科领域长期关注的基础科学问题。**李阿明研究员课题组**与合作者首次揭示了时滞效应对复杂系统稳定性的非单调影响。进一步，他们还通过引入反应性的概念弥补了稳定性在刻画复杂系统短期动力学行为方面的不足。他们的研究成果有助于深入理解

真实复杂系统的动力学行为，为建立有效的复杂系统调控策略提供了理论基础。

Towards an in-depth understanding of dynamical behaviors of complex systems

Understanding the stability of complex systems, whether a system can recover from external perturbations, is a long-standing fundamental scientific issue concerned by various disciplines. For the first time, **Aming LI** group and collaborators reveal the non-monotonic influence of time delay on the stability of complex systems. Furthermore, by introducing the concept of reactivity, they address the shortcoming of stability in characterizing the short-term dynamical behaviors of complex systems. Their research results contribute to an in-depth understanding of the dynamical behaviors of real-world complex systems and provide a theoretical foundation for the development of effective strategies for regulating complex systems.



Yang, Y., Foster, K.R., Coyte, K.Z., Li, A. Time delays modulate the stability of complex ecosystems. Nat Ecol Evol 7, 1610–1619 (2023).

Yang, Y., Coyte, K.Z., Foster, K.R., Li, A. Reactivity of complex communities can be more important than stability. Nat Commun 14, 7204 (2023).

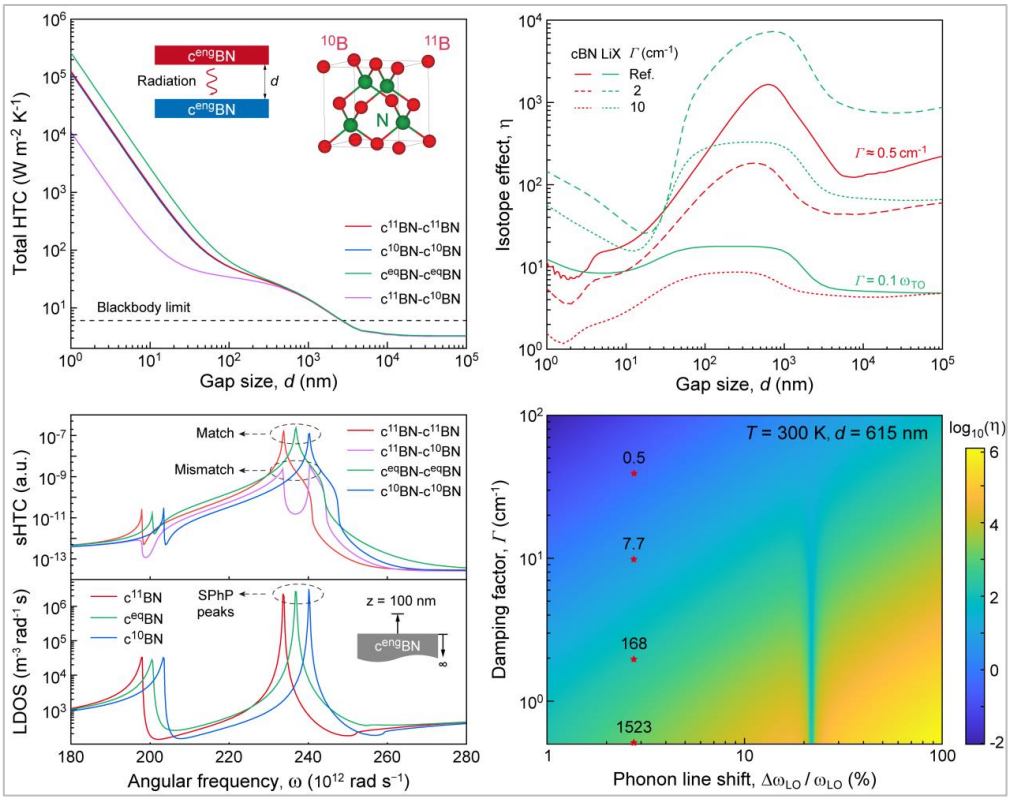
72．热辐射的同位素效应

热辐射是电荷热涨落引发的电磁波，百余年前对于黑体的先驱研究，最终点燃了量子革命。**宋柏研究员课题组**首次理论预言并系统阐释了热辐射的同位素效应。该工作是热辐射领域漫长历史上的一次重要探索，在辐射换热、声子物理和同位素科学之间建立了桥梁，既为深刻理解基本规律开辟了新方向，也为极致调

控提供了新方法，有望用于高效热能转换、智能热管理和太空探索。

Isotope effect on radiative thermal transport

Thermal radiation originates from the incessant fluctuations of charge carriers. The pioneering studies of blackbody in the nineteenth century eventually lead to the quantum revolution. For the first time in the long history, **Prof. Bai SONG** and his team theoretically discovered and systematically revealed the isotope effect on thermal radiation, in a work that bridges the fields of radiative thermal transport, phonon physics, and isotope science. This work not only opens up new avenues for gaining fundamental insights, but also for the extreme control of thermal radiation, and may find applications in energy conversion, thermal management, and space exploration.



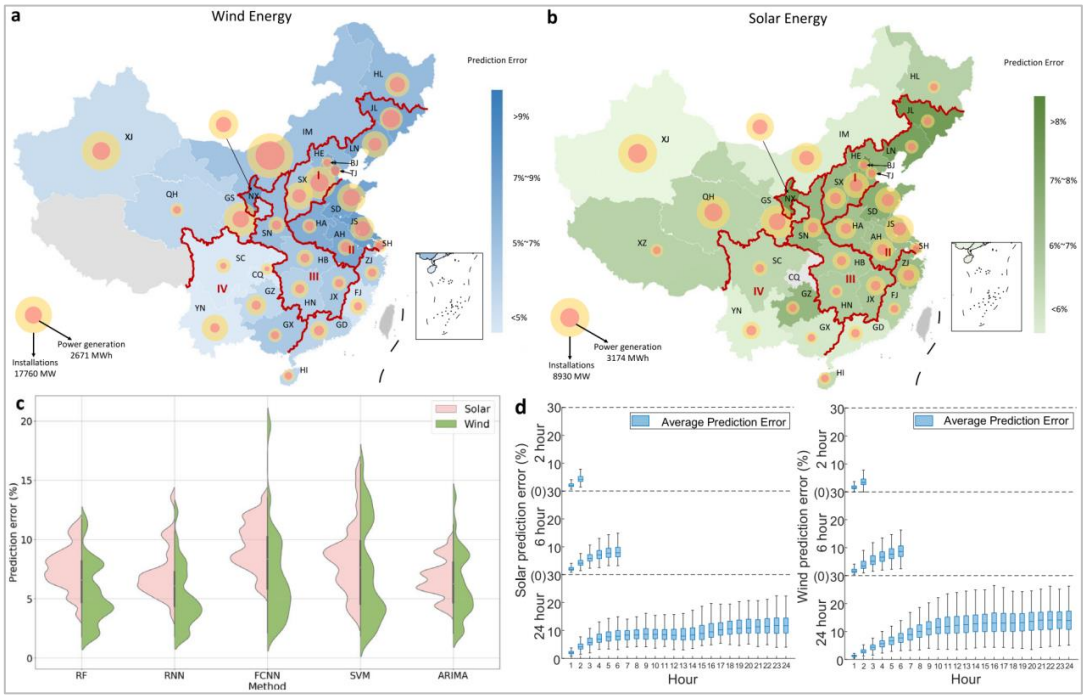
L. Xie and B. Song, Isotope effect on radiative thermal transport, Phys. Rev. B 107, 134308 (2023). Highlighted by B. Grocholski et al., Science 380, 809 (2023).

73．基于数据价值探索可再生能源不确定性分布的时空规律

可再生能源的不确定性为建设低碳能源系统的安全稳定运行带来重大挑战。**宋洁教授团队**针对国家分省级、年度小时级的可再生多尺度的数据，设计了统计推断与深度学习结合的多元算法，构建了基于预测误差分析的可再生能源多时空不确定性的数据价值分析方法，发现时间序列一阶差分和尖峰比例是影响随机分布的关键可解释因素，进而揭示了我国 30 个省份风力和光伏发电随机分布的时空规律，为低碳转型路径的实现提供量化依据。

Inherent spatiotemporal uncertainty of renewable power in China

The inherent uncertainty of renewable energy will pose significant challenges to the safe and stable operation of future low-carbon energy systems. **Prof. Jie SONG** and her team proposed a multiscale spatiotemporal uncertainty analysis method for renewable energy based on predictive error analysis. They constructed a standard database of renewable energy forecast error distribution driven by a combination of statistical learning, deep learning, and other algorithms at a provincial and hourly level. They found that the first-order difference and peak ratio of generation series are primary indicators explaining the uncertainty distribution. They revealed the spatial and temporal random patterns of wind and photovoltaic power generation in 30 provinces of China.



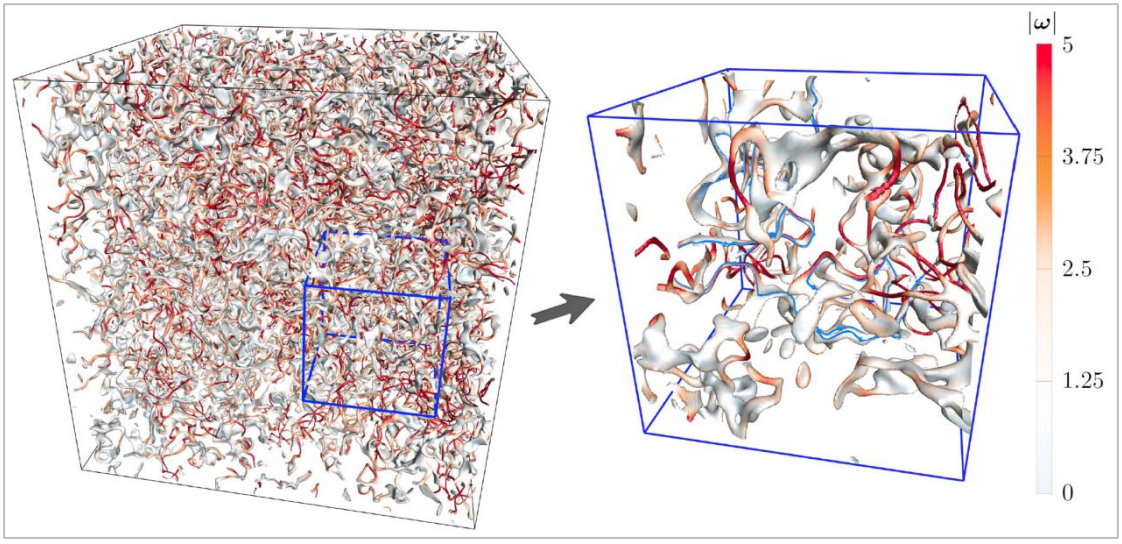
Wang, J., Chen, L., Tan, Z., Du, E., Liu, N., Ma, J., Sun, M., Li, C., Song, J., Lu, X., Tan, C.W, & He, G. Inherent spatiotemporal uncertainty of renewable power in China. Nature Communications, 14(1), 5379, 2023.

74．基于薛定谔方程的流体力学量子计算方法

杨越教授课题组提出了一类基于流体薛定谔方程的量子计算方法，可望利用量子计算效率优势模拟三维湍流等复杂流动问题。该流体薛定谔方程通过推广 Madelung 变换获得，描述了含动能耗散和有限涡量的不可压/可压缩流动。与现有流体力学计算方法完全不同的是，流体薛定谔方程的量子模拟中只包含波函数相关信息，等价为一个特殊的量子力学系统。该研究发展了相应量子算法，并使用多个量子比特在量子模拟器上对简单流动进行了算法验证，实现了相较于经典计算的部分指数加速。后续可望在现有含噪中等规模量子硬件平台上实现流体动力学模拟。

New equation enables quantum computing of fluid dynamics

A new method is developed to simulate fluid dynamics on a quantum computer by tweaking the equation of quantum mechanics. Solving the hydrodynamic Schrödinger equation can be implemented as the quantum simulation of a special quantum system, where the unknown variable is a two-component wave function. Classical physical quantities such as fluid density and velocity are then obtained by measuring the wave function after multiple repeated simulations. The simulated flow shows very chaotic and entangled vortex tubes as in classical turbulence. A quantum algorithm with a partial exponential speedup is developed.



Tangled vortex tubes for isotropic turbulence in the incompressible Schrödinger flow. Z. Meng and Y. Yang, Quantum computing of fluid dynamics using the hydrodynamic Schrödinger equation, Physical Review Research, 5, 033182, 2023.

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

75．知识云智能问答系统

赵东岩研究员团队基于自然语言理解、智能知识标注、问题意图理解、知识图谱等方法，构建 “知识云习近平新时代中国特色社会主义思想智能问答平台”。该平台通过智能问答、知识推荐等方式，实现思想理论的知识化解读，提供一个易学易会、融会贯通的智能问答学习平台。目前，该系统已在新华社上线试运行。

Intelligent Q&A System

Prof. Dongyan ZHAO and his team builds the cloud platform of “Xi’s Articles Intelligent Q&A System”, which is based on natural language understanding, intelligent knowledge annotation, question intent understanding, and

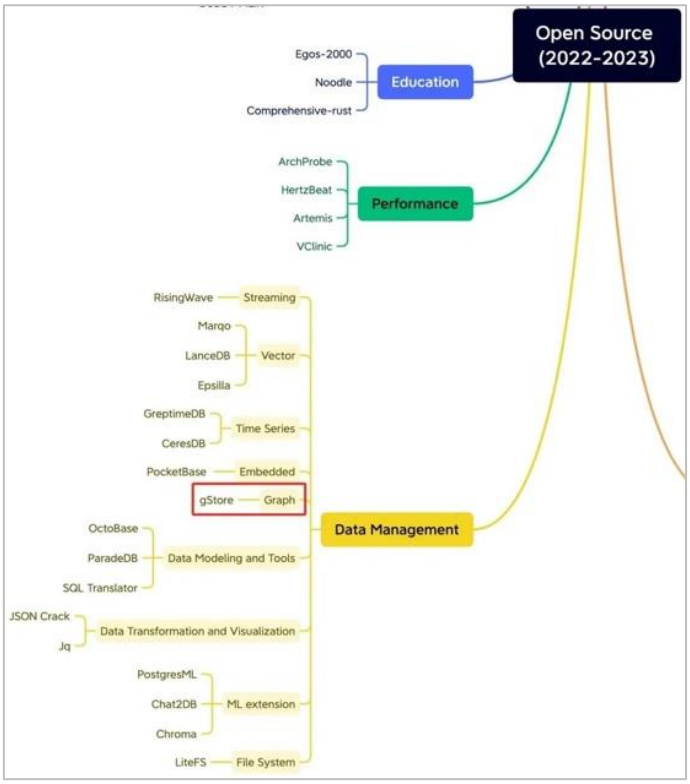
knowledge graph. The platform provides an assistant of learning ideas and theories through intelligent Q&A and knowledge recommendation. At present, the system has been put on line for trial operation in Xinhua News Agency.

76．研发的数据库系统 gStore 入选年度世界开源贡献榜

邹磊教授团队主持研发面向知识图谱的开源图数据库系统经过 10 余年的学术深耕与工程研发，创新性地提出以“子图匹配”为核心的构建图数据库查询引擎等核心技术，多次获得国际重要学术会议的最佳论文奖；所研发的图数据库系统 gStore 已应用于政府大数据服务、金融风控管理、知识出版与文化传播等诸多领域，并入选 BenchCouncil（国际测试委员会）所遴选的 102 项代表性成果的 2023 年度世界开源贡献榜。

The graph database system gStore developed was selected as opensource achievement from 2022 to 2023

Prof. Lei ZOU's team led the research and development of an open-source graph database system for knowledge graphs. After more than 10 years of academic research and engineering development, they proposed some core technologies of a native graph database system, such as subgraph match-based query processing and optimization strategy, and won several best paper awards at important international academic conferences. The graph database system gStore developed by the team has been applied in many fields such as government big data services, financial risk management, knowledge publishing and cultural communication, and was selected as one of the 102 representative opensource achievements by BenchCouncil (International Testing Committee).

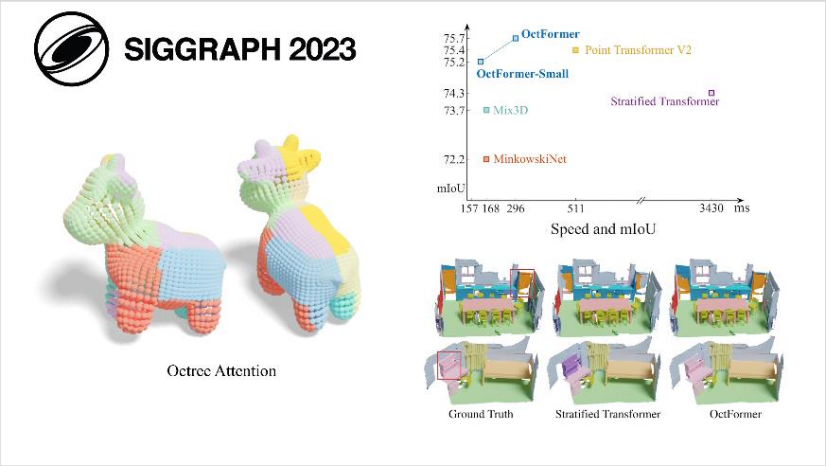


77．基于八叉树的三维注意力机制网络

注意力机制神经网络（Transformers）在自然语言和图像的理解和生成中取得巨大突破，但一直无法高效地处理三维数据。**王鹏帅助理教授**以独立作者身份在计算机图形学国际顶会 SIGGRAPH 2023 发表期刊论文，提出了基于八叉树的三维注意力机制网络(OctFormer)，将现有的三维注意力机制效率提升至少 20 倍，使得理解与生成高分辨率的三维数据成为可能，为通用人工智能模型在处理三维数据方面提供了坚实的基础。王鹏帅也于 2023 年获得了 AsiaGraphics 青年学者奖，该奖项在亚太地区每年评选至多一名具有国际影响力的青年学者，用于表彰其在三维图形学领域所做出的突出贡献。

OctFormer: Octree-based 3D Transformers

Transformers have made great breakthroughs in the understanding and generation of natural language and images, but they were unable to process 3D data efficiently. **Peng-Shuai WANG** published a journal paper as an independent author at SIGGRAPH 2023, the top international conference on computer graphics. In this paper, he proposes Octree-based 3D transformers (OctFormer), which improves the efficiency of the existing methods by at least 20 times, providing a solid foundation for general artificial intelligence models in processing 3D data. Peng-Shuai Wang also won the AsiaGraphics Young Scholar Award in 2023. This award selects at most one influential young scholar in the Asia-Pacific region every year to commend his outstanding contributions in the field of 3D computer graphics.



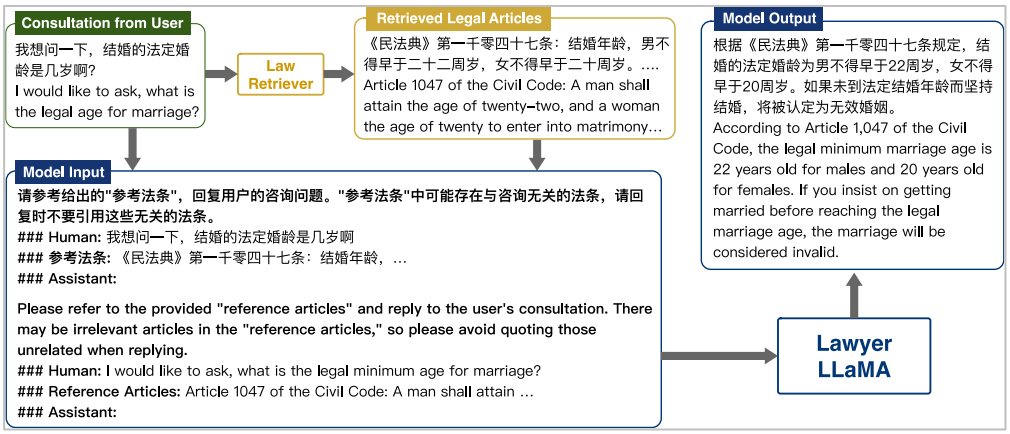
Peng-Shuai Wang. OctFormer: Octree-based Transformers for 3D Point Clouds. ACM Transactions on Graphics (SIGGRAPH), 42(4), 2023.

78．中文法律大模型 Lawyer LLaMA

以 ChatGPT 为代表的生成式大语言模型在通用领域表现惊人，但缺乏如法律等专业领域的知识和技能，难以有效解决相关领域的现实问题。**冯岩松副教授**团队首次将法律职业资格考试和法律咨询引入预训练与微调过程，使得大语言模型系统学习中国法律知识体系，习得领域分析技能，成功构建了首个中文法律大模型 Lawyer LLaMA，在法律咨询等实际场景中表现优异，同时也为后续其他垂直领域大模型的构建提供了可借鉴的技术路线。

Lawyer LLaMA, a Large Language Model for Chinese Legal Domain

Although large language models (LLMs) such as ChatGPT have shown great performance in general domains, they still lack necessary expertise in specific domains such as law, hindering their ability to tackle real-world challenges. **Dr. Yansong FENG** and his research team developed Lawyer LLaMA, a pioneering Chinese legal LLM, which has systematically acquired legal knowledge in Chinese and is equipped with necessary problem-solving skills to tackle real-world challenges. Lawyer LLaMA has demonstrated excellent performance in various practical scenarios and paves a viable roadmap for future research in domain-specific LLMs construction.



Lawyer LLaMA: Enhancing LLMs with Legal Knowledge, Q. Huang, M. Tao, C. Zhang, Z. An, C. Jiang, Z. Chen, Z. Wu, Y. Feng, arXiv:2305.15062, 2023.

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

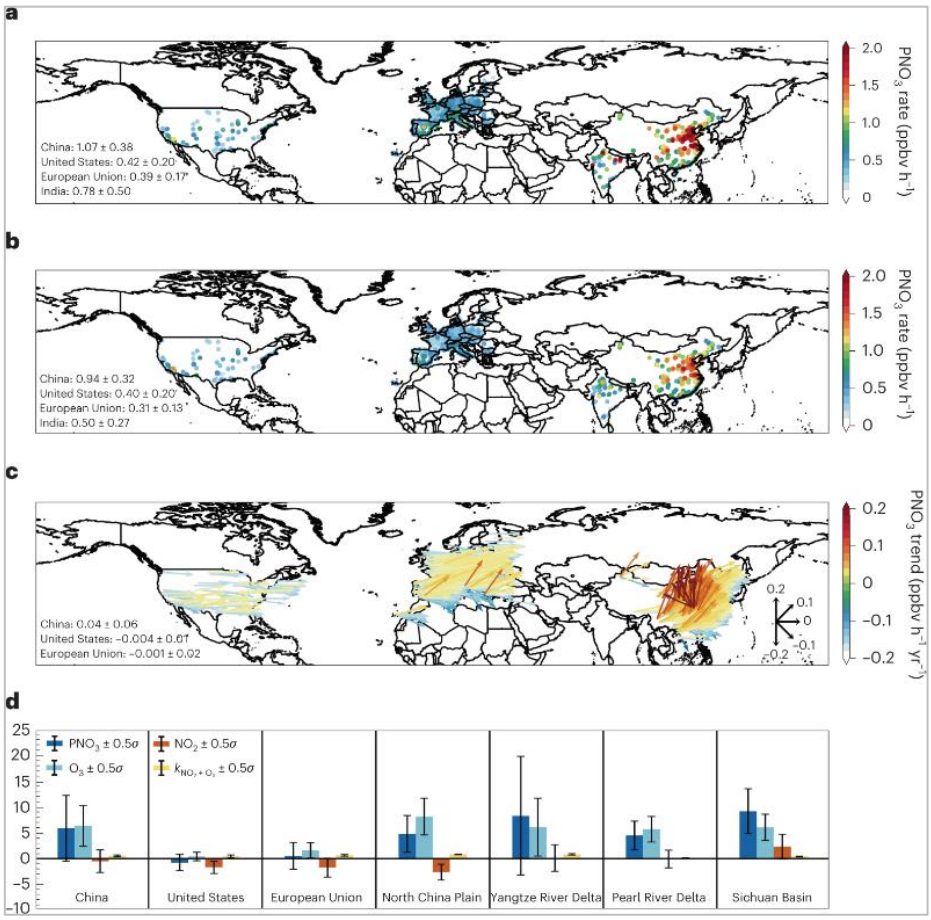
79．揭示全球夜间大气氧化性的演变及其调控机制

探究夜间大气氧化性演变趋势对制定区域空气污染防控策略和减污降碳的协同应对至关重要，但全球夜间大气氧化过程的演变规律和调控机制还尚未得到充分认识。**陆克定研究员和张远航院士团队**收集和分析了全球 NOx 和 O_3 监测数据，系统评估了 2014 年至 2021 年全球近地面 NO_3 的生成速率和趋势，首次构建了统一描述夜间氧化能力对 NOx 减排非线性响应的理论关系模型，阐明了 NOx 和 VOC 协同减排的关键意义，为全球各大城市群的大气污染控制提供了新的视角，并对其他发展中国家的空气污染治理具有重要的参考价值。

The dark side of the air pollution trends

Nocturnal atmospheric oxidation is a process that is critical to air quality and climate through its regulation of both ozone (O3) and PM2.5 pollution. Despite this importance, the spatiotemporal variability of nighttime oxidation and its impacts on a global scale has never been well quantified.

Using a comprehensive surface observational dataset, **Prof. Keding LU and Prof. Yuanhang ZHANG** organized an international joint research team including Peking University and Sun Yat-sen University in China, and the NOAA Chemical Sciences Laboratory in the United States. The team identified a nighttime oxidation “hot-spot” in China, represented by rapid production of a potent nighttime oxidant that results from the dark atmospheric chemistry known as the nitrate radial, NO3. They constructed a novel framework to characterize the evolution of nighttime oxidation on emission changes. The new work shows that explicit consideration of the response of ozone and particulate matter to nighttime chemical processes in future modeling studies will be of substantial importance to assessment of air quality and climate responses to emissions changes.



Observed level and trend of nocturnal nitrate radical production rate (PNO3) in the warm season (April – September). Wang, H., Wang, H., Lu, X. et al. Increased night-time oxidation over China despite widespread decrease across the globe. Nat. Geosci. 16, 217–223 (2023). https://doi.org/10.1038/s41561-022-01122-x

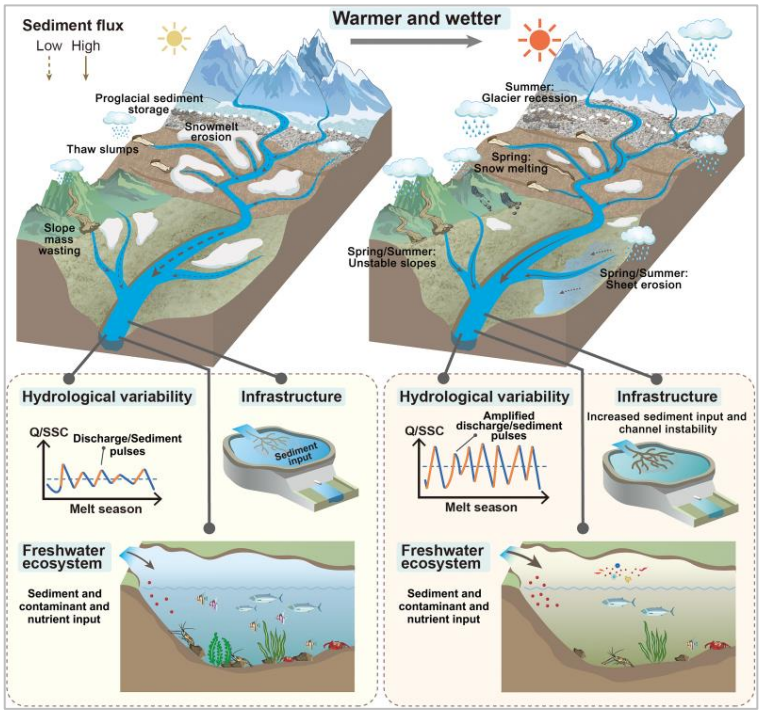
80．揭示气候变化下冰冻圈河流水沙输移季节性变化新机制

气候变化和冰冻圈退化对冰冻圈河流的水沙通量影响显著。目前对气候变化下冰冻圈河流水沙输移的季节性变化机制尚不明确，难以为制定冰冻圈河流气候变化适应对策以及流域可持续管理提供有效的科技支撑。**李东锋研究员课题组**在通过辨识四种典型的冰冻圈河流，揭示了冰冻圈河流泥沙输移季节性变化的新机制，构建了流域泥沙输移模型（SAT-M），实现了对不同类型冰冻圈河流泥沙输移季节性变化的精准模拟和复现，指出了冰冻圈河流水沙输移的季节性变化对河道演变、洪水灾害、水库运行和生态系统稳定性的影响。

The seasonal river regime shifts in cryosphere-fed basins

Climate change and cryosphere degradation have remarkably impacted riverine water and sediment fluxes from polar and high-mountain regions. However, the responses of seasonal dynamics and regime shifts in sediment transport remain largely understudied due to the lack of long-term and fine-scale hydrological records and the complexity of the underlying hydrogeomorphic processes.

Prof. Dongfeng LI's group in College of Environmental Sciences and Engineering, Peking University, they identified the climate-driven regime shifts in suspended sediment transport in four distinct basins in the Third Pole, characterized as glacial, nival, pluvial, and mixed hydrological regimes and developed a monthly scale sediment-availability-transport model (SAT-M) to simulate climate-driven sediment dynamics and reproduce such regime shifts. SAT-M can help facilitate sustainable reservoir operation and river management in wide cryospheric regions under future climate and hydrological change.



Increased sediment sources, amplified hydrological variability, and associated social-ecological impacts. Ting Zhang et al. Shifted sediment-transport regimes by climate change and amplified hydrological variability in cryosphere-fed rivers.Sci. Adv.9,eadi5019(2023).

81．提出大气活性氮外部循环特征

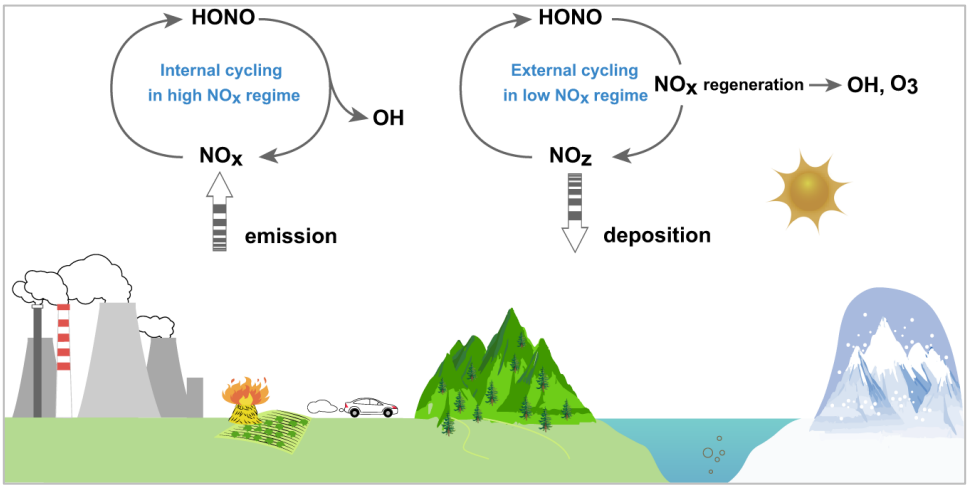
氮氧化物（NOx=NO+NO2）和气态亚硝酸（HONO）是重要的大气活性氮物种，它们参与自由基生成和循环，深刻影响大气氧化性。除内部循环外，NOx 和 HONO 也能够由 NOz 通过表面催化、微生物活动等途径再循环生成，即活性氮的“外部循环”。在背景地区（低 NOx 环境），外部循环是 NOx 和 HONO 的重要来源，进而极大地促进当地内部循环、自由基以及 O_3 的化学生成。然而，当前对外部循环特征及其环境影响的认识仍有很大的不确定性。**叶春翔研究员课题组**提出了一种认识外部循环的新视角，即利用外场观测数据分析总结外部循环特征、量化外部循环的环境影响。团队依托 NSF/NCAR C-130 航测平台，研究收集了大气活性氮及其循环相关物种的 19 次航测数据；利用 GEOS-Chem 全球模式模拟了观测同期的活性氮及其循环相关物种浓度，提供了内部循环情境下活性氮的基准分布特征。结果表明外部循环在维持背景大气环境活性氮浓度水平和分布特征

上具有决定性作用。外部循环进而促进背景大气 OH 自由基初次生成和循环生成，提升背景环境大气氧化性。

The characteristics of the external cycle of reactive nitrogen

In high-NOx environments, nitrogen oxides (NOx) and nitrous acid (HONO) are coupled in their internal cycling. Given the catalytic role of NOx in radical chain propagation, external cycling further promotes the formation of hydroxyl radical, the most important oxidant in the atmosphere. However, the external cycling of NOx has not been fully validated due to its large variability and potentially large uncertainties in its kinetics and mechanisms across the high- to low-NOx atmospheres.

Researcher Chunxiang Ye and his research team suggest synthesizing observational and model evidence, summarizing the fundamental characteristics of external cycling, and quantifying its impact on the oxidative capacity of the atmosphere. The results indicate the dominant role of external cycling in the chemical budget of reactive nitrogen in low-NOx atmospheres and its significant impact on oxidant photochemistry, and provide new insights into reactive nitrogen chemistry by synthesizing observational evidence across high- to low-NOx atmospheres rather than attempting to establish the kinetics or the dominant mechanism.



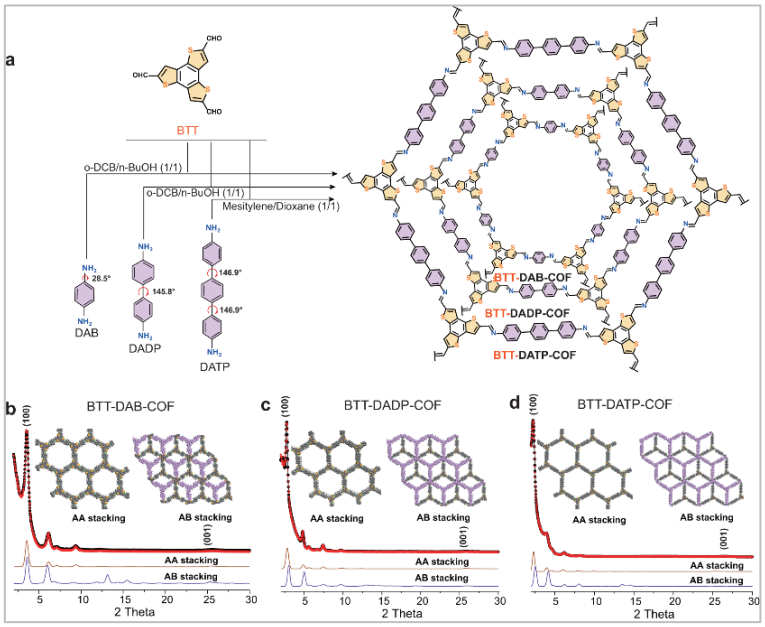
The left reaction scheme describes internal cycling between nitrogen oxides (NO = NO + NO) and nitrous acid (HONO) in high- NO atmospheres. HONO photolysis is the major route producing OH radical (OH). The right reaction scheme describes external cycling among oxidative reservior species of NO (NO), NO, and HONO in low-NO atmospheres. NO -catalysed radical chain propagration takes over as the major route perturbing OH and ozone (O) chemical production. Ye, C., Zhou, X., Zhang, Y. et al. Synthesizing evidence for the external cycling of NOx in high- to low-NOx atmospheres. Nat Commun 14, 7995 (2023).

82．报道了适用于水中抗生素高效降解的新型功能材料及构架方案

新污染物是目前我国生态环境保护的重要关注点。抗生素是一类典型的有机新污染物，污/废水中痕量级抗生素的去除是水处理的重点和难点。绿色、高效的新型水处理技术的开发迫在眉睫。**刘文研究员课题组**通过框架化学原理，理性设计和制备了新型共价有机网状结构材料（Covalent-organic frameworks，COFs），发现了微污染物净化过程中功能分子基元的扭曲性与疏水性的双协同效应。

Twistedly hydrophobic basis with suitable aromatic metrics in covalent organic networks govern micropollutant decontamination

Water crisis caused by emerging microcontaminants including pharmaceuticals and endocrine-disrupting chemicals poses great threats to human health. However, the fact that how to achieve efficient photochemical decomposition of pollutants while reducing energy consumption in water treatment has been long ignored. **Researcher Wen LIU** and his team have rationally explored an integrated interfacial design strategy for constructing an active and robust catalyst for photochemically decomposing contaminants. This study provides an insightful avenue of synergistically regulating electronic structure and interfacial reaction based on organic porous networks toward an energy-saving and cost-reducing way for water purification.



a Schematic represented of the syntheses of BTT-based COFs with different pore size, termed as BTT-DAB-COF, BTT-DADP-COF, and BTT-DATP-COF. b–d Experimental, refined and simulated PXRD patterns of BTT-DAB-COF, BTT-DADP-COF, and BTT-DATP-COF. Qin, C., Yang, Y., Wu, X. et al. Twistedly hydrophobic basis with suitable aromatic metrics in covalent organic networks govern micropollutant decontamination. Nat Commun 14, 6740 (2023).

83．揭示粮食系统增效是我国实现碳中和的关键

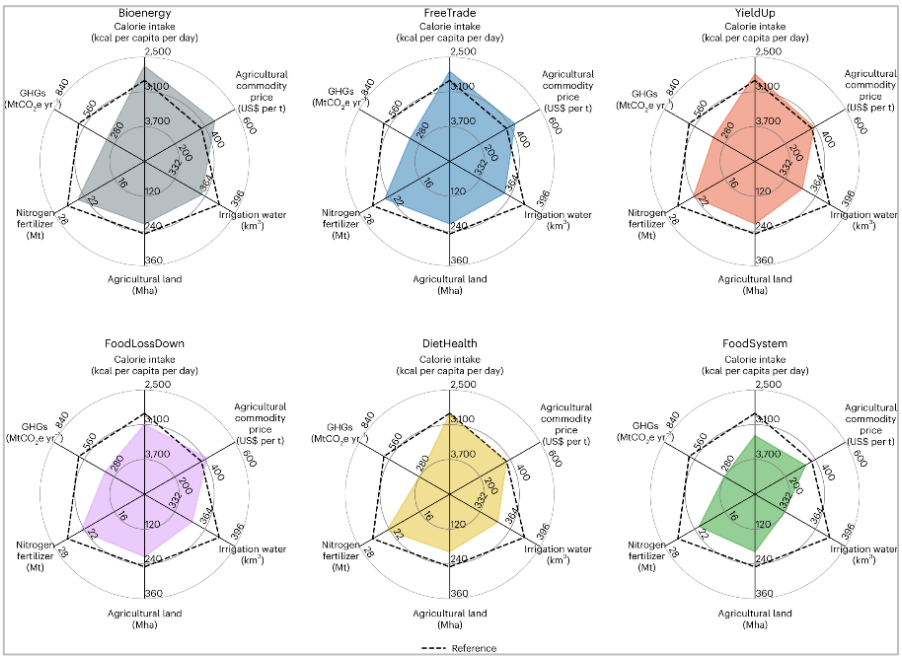
生物质能-碳捕捉与封存技术（BECCS）对实现《巴黎协定》的气候减缓目标至关重要。为应对气候变化而大规模种植能源作物会引发与土地相关的多维可持续性问题。当前亟待解决的科学问题是：如何在不危及我国粮食安全、不加重粮食贸易伙伴国环境负担的前提下，提供大规模的生物质能源？针对这一问题，**戴瀚程研究员课题组**与合作者基于自主构建的北京大学 IMED-GLOBIOM 综合评估模型体系，探索了大规模生产生物质能如何助力中国碳中和目标实现而不对国内外可持续发展产生负面影响。这将为统筹生物质能负排放技术布局、粮食安全供应、全球粮食贸易合作等多维度政策以实现碳中和提供学理支撑和前瞻见解。

Enhanced food system efficiency is the key to China’s 2060 carbon neutrality target

Bioenergy with carbon capture and storage, among other negative-emission technologies, is required for China to achieve carbon neutrality—yet it may hinder land-based Sustainable Development Goals.

Bioenergy with carbon capture and storage is pivotal for meeting the ambitious climate mitigation targets set by the Paris Agreement. However, large-scale bioenergy deployment to combat climate change triggers multiple land-based sustainability concerns.

Using the Global Biosphere Management Model (GLOBIOM)–China model and scenario analysis, **Researcher Hancheng DAI**’s Group investigate how to mitigate the potential adverse impacts on the food system of ambitious bioenergy deployment in China and its trading partners. The results show that simultaneously achieving carbon neutrality, food security and global sustainability requires a careful combination of these measures.



The six sustainability indicators include daily per capita calorie intake, agricultural commodity prices (2000 constant prices), irrigation water, agricultural land (cropland and grassland), nitrogen fertilizer and GHG emissions from AFOLU. Ren, M., Huang, C., Wu, Y. et al. Enhanced food system efficiency is the key to China's 2060 carbon neutrality target. Nat Food 4, 552–564 (2023).

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

84．代码大模型 CodeShell-7B

2023 年 10 月，**张世琨研究员团队**在 Github 上开源 70 亿参数的代码基座大模型 CodeShell。截止 11 月 15 日，CodeShell 在 Hugging Face 国际权威开源代码大模型榜单中同等规模排名第一（与 CodeLLaMA 并列）。CodeShell 发布两天即登上 Github 趋势榜（Python 项目排名第一），两周内 Star 数量超过 1200，下载量过万，引发中国新闻网、新智元、Medium 等国内外主流媒体报道，取得了较大的社会影响力。

Code Large Language Model CodeShell-7B

In October 2023, the National Engineering Research Center for Software Engineering of Peking University open-sourced the 7-billion-parameter code large language model CodeShell on GitHub. As of November 15, CodeShell ranked first among 7-billion-parameter code large language models on the Big Code Models Leaderboard on Hugging Face Platform, tied with CodeLLaMA. Within two days of its release, CodeShell topped the GitHub Trending chart (ranking first among Python projects), and within two weeks, it garnered over 1,200 stars and more than ten thousand downloads, drawing coverage from mainstream media at home and abroad, including China News Service, XinZhiYuan, and Medium, achieving significant social impact.

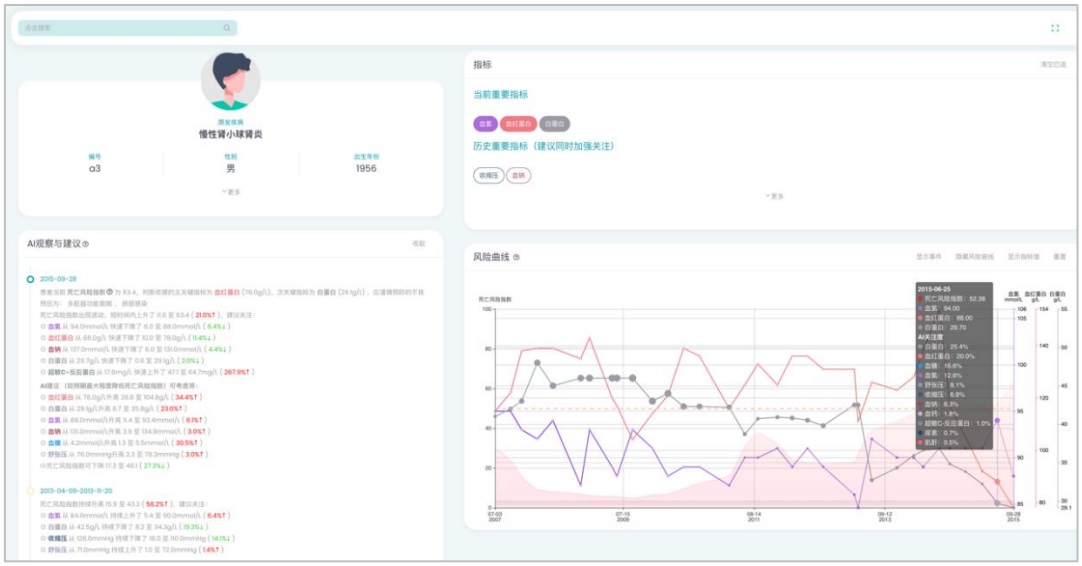
T	Models	Win Rate	humaneval-python
🟢	CodeLlama-7b	21.08	29.98
🔴	CodeShell-7B	21.08	34.32
🔶	OctoCoder-15B	19.92	45.3
🟢	Falcon-180B	19.9	35.37
🟢	CodeLlama-7b-Python	19.46	40.48
🟢	StarCoder-15B	19.35	33.57
🟢	StarCoderBase-15B	18.92	30.35
🟢	CodeGeex2-6B	16.35	33.49
🟢	StarCoderBase-7B	15.92	28.37
🔶	OctoGeeX-7B	15.73	42.28

85．智能辅助诊疗系统：小雅医生

王亚沙教授团队研制的融合了基于多模态电子病历训练建立的多个深度学习模型，包括：疾病诊断、预后预测和治疗建议生成等，并且可以对模型建议给出决策证据，增强了模型的可解释性和实用性。相关研究成果在 TKDE、ICML、KDD、AAAI 等多个国际顶级学术期刊和会议发表论文 20 余篇，模型性能超过国际同期最佳模型。人工智能辅助诊疗平台——小雅医生，已经在北京大学第三医院和人民医院、江苏省人民医院等 6 所三甲医院试用，效果良好。

Intelligent Assisted Diagnosis and Treatment System: Doctor XiaoYa

Doctor XiaoYa is an intelligent assisted diagnosis and treatment system developed by the National Engineering Research Center for Software Engineering of Peking University. The system integrates multiple deep learning models trained on multimodal electronic medical records, including models for disease diagnosis, prognosis prediction, and treatment recommendation. It can also provide decision evidence for the model's recommendations, enhancing the interpretability and practicality of the model. The related research results have been published in more than 20 papers in top international academic journals and conferences such as TKDE, ICML, KDD, and AAAI, with model performance surpassing the best international models of the same period. Doctor XiaoYa has been trialed in six top-tier hospitals including Peking University Third Hospital, Peking University People's Hospital, and Jiangsu Provincial People's Hospital, with good results.



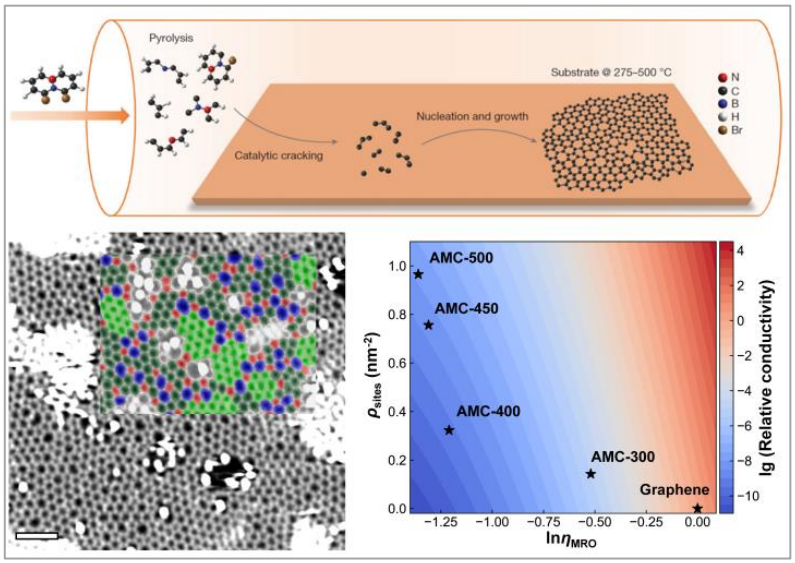
材料科学与工程学院（School of Materials Science and Engineering）

86．二维非晶碳材料的无序度调控和构效物理

原子构型的精准解析和结构-性质关联是非晶物质科学研究长期存在的重大挑战。**刘磊研究员**课题组及合作者在二维非晶碳材料中首次实现了无序度的调控及微观原子结构-宏观电学性质的定量关联。该工作揭示了二维非晶材料的结构、性质高度可调性，为其器件应用奠定了基础。

Disorder-Tuned Conductivity in Amorphous Monolayer Carbon

Precisely determining atomic configurations and its structure-property relationship are the holy grail of amorphous materials research. For the first time, **Assistant Prof. Lei LIU** and collaborators have realized the control of degree of disorder and the quantitative correlation of micro atomic structure and macro electrical properties in amorphous monolayer carbon. This work reveals the high tunability of structures and properties of two-dimensional amorphous materials, and lays the foundation for their device applications.



H. Tian, Y. Ma, Z. Li, M. Cheng, S. Ning, J. Chen, W. Zhou*, and L. Liu* et al. Disorder-Tuned Conductivity in Amorphous Monolayer Carbon. Nature, 2023, 615, 56-61.*

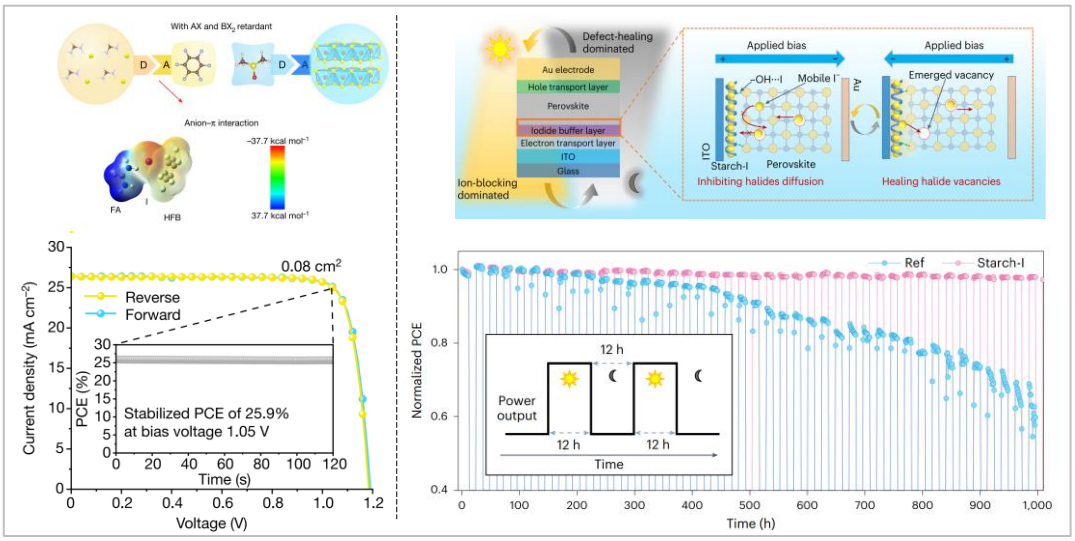
87．高效稳定钙钛矿太阳能电池

钙钛矿太阳能电池是下一代光伏技术的典型代表。然而，钙钛矿太阳能电池仍面临着材料制备不可控和本征不稳定的关键难题，**周欢萍教授团队**开发了阴离子-π 相互作用及超分子主客体化学策略等新方法，大幅抑制了纳米尺度相杂质的形成及离子迁移行为，获得了高效稳定的钙钛矿电池器件，其光电转换效率超过 26%（第三方认证值 25.8%），且长期运行稳定性及昼/夜循环运行稳定性得到

明显改善。该系列工作为高性能钙钛矿太阳能电池的制备和器件稳定性提升奠定了坚实基础。

High-efficiency and stable perovskite solar cells

Perovskite solar cells serve as a typical representative of the next generation of photovoltaic technologies. Nevertheless, these devices encounter formidable challenges, including uncontrollable material preparation and intrinsic instability. To tackle these issues, **Prof. Huanping ZHOU** and collaborators have developed new methods, including anion-π interaction and supramolecular host-guest chemistry strategies. These approaches effectively mitigate the formation of nanoscale phase impurities and ion migration behaviors, resulting in perovskite solar cells that exhibit both high efficiency and stability. The photovoltaic conversion efficiency of these devices exceeds 26% (certified 25.8%), accompanied by noticeable improvements in long-term operational stability and day/night cycle stability. These studies lay the foundation for the precise fabrication of high-performing perovskite solar cells with enhanced stability.



Huang, Z., Bai, Y., Huang, X. et al. Anion–π interactions suppress phase impurities in FAPbI3 solar cells. Nature 623, 531–537 (2023).

Zhang, Y., Song, Q., Liu, G. et al. Improved fatigue behaviour of perovskite solar cells with an interfacial starch–polyiodide buffer layer. Nat. Photon. 17, 1066–1073 (2023).

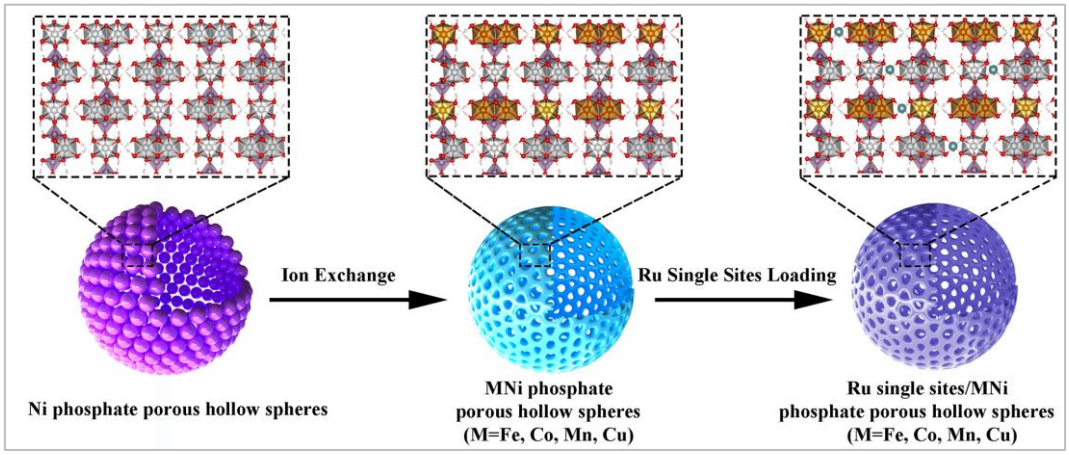
88．发现稳定高价态钌催化活性位的新策略

工业电流密度下高效电解水催化剂的制备是实现大规模制绿氢的关键。**郭少军教授课题组**发展了一种局域电子结构调控的新策略稳定高价态 Ru 原子（Ru SS）锚定于 Ni 基金属磷酸盐多孔空心球。不同电位下 X 射线吸收精细结构谱和密度泛函理论计算联合验证了制备的 Ru 基催化剂的本征稳定性。研究建立了描述高价态 Ru SS 优越电催化性能的双火山型曲线，提出了稳定高价 Ru SS 催化位点的基本准则。使用 Ru SS FeNiPi PHSs 作为阴阳极电极材料，在低 Ru 负载

量（0.081 mg cm^{-2}）的工业级电解槽中，实现了 1.78 V 电压下 2000 mA cm^{-2} 大电流密度高效稳定运行，同电压下电流密度是基于商业化 Pt//RuO_2 膜电极电流密度的 5.7 倍。该工作提供了一种可稳定高价态 Ru SS 的局域电子结构调控新策略，为实现高活性和高稳定 Ru 基电解水材料实现工业电解水提供了新思路。

Innovating new strategy of stabilizing high-valence ruthenium for acidic oxygen evolution electrocatalysis

Large-scale production of green hydrogen requires highly-efficient electrocatalysts that can deliver high current density for oxygen evolution reaction (OER). Ru shows impressive OER activity yet encounters poor stability. In this context, **Prof. Shaojun GUO** and collaborators designed a local electronic manipulation strategy that efficiently stabilizes high-valence Ru single sites (Ru SS) on a class of Ni-based phosphate porous hollow spheres. Both in-situ X-ray absorption fine structures spectra and density functional theory calculations verified the effectiveness of this strategy and improved intrinsic stability of as-obtained catalyst. On these basis, general guidelines were formulated for stabilizing high-valence catalytic sites, which introduced a double-volcano plot to describe the superior electrocatalytic behaviors of high-valence Ru SS. To further demonstrate the practicability, as-designed Ru SS/FeNiPi was further integrated into an industrial-level electrolyzer with a low Ru loading of 0.081 mg cm-2 realizes a stable industrial current density of 2,000 mA cm-2 at 1.78 V, which is the highest reported value in alkaline electrolyte, and exceeds that of commercial Pt//RuO2 by 5.7 times. This work provides a new strategy to control the local electronic structure of Ru SS, which can stabilize the high valence state of Ru and provide a new material platform for industrial water electrolysis.



Synthetic tuning stabilizes a high-valence Ru single site for efficient electrolysis. Shi-Yu Lu, Bolong Huang, Mingzi Sun, Mingchuan Luo, Meng Jin, Huawei Yang, Qinghua Zhang, Hui Liu, Peng Zhou, Yuguang Chao, Kun Yin, Changshuai Shang, Junmei Wang, Yan Wang, Fan Lv, Lin Gu &Shaojun Guo Nature Synthesis 2023, https://doi.org/10.1038/s44160-023-00444-x.*

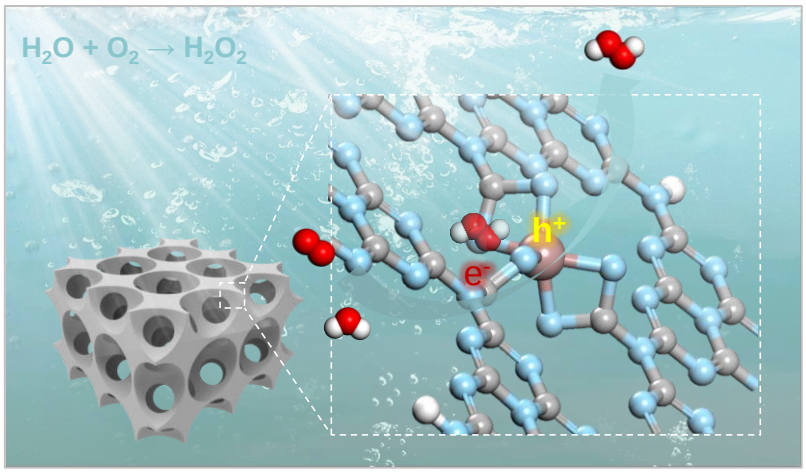
89．发现了人工光合成过氧化氢的高效 Ga-N5 原子位光催化剂

开发高效光催化剂利用光能实现水和氧气直接合成过氧化氢具有重要科学意义和潜在应用价值。**郭少军教授团队**开发了一类 Ga 原子位锚定于反蛋白石结构氮化碳的光催化剂（CNIO-GaSA），发现该新型催化剂具有独特的 GaN_5 原子活性位，可实现高效两电子水氧化+两电子氧还原路径合成过氧化氢。CNIO-GaSA 产生过氧化氢的太阳能转换效率为 0.4%，远高于自然界植物光合作用的能量转化效率（~0.1%）。基于团队自主设计和组装的光催化器件可实现对过氧化氢的流动型生产，并可实现未名湖水原位高效杀菌。该工作提供了一种两电子水氧化和两电子氧还原人工光合成过氧化氢的新思路。

Constructing Ga-N5 atomic site catalyst for artificial photosynthesis of hydrogen peroxide

Hydrogen peroxide photosynthesis from water, air and sunlight is highly appealing for a sustainable future. **Prof. Shaojun GUO** and co-workers rationally designed and controllably synthesized a class of photocatalyst with Ga-N5 atomic site dispersed on macroporous inverse-opal-type carbon nitride (CNIO-GaSA). This photocatalyst owns a unique Ga-N5 atomic site that can efficiently convert water into hydrogen peroxide via a metastable two-electron water oxidation pathway. The CNIO-GaSA photocatalyst also delivered a high solar-to-chemical conversion efficiency of 0.4%, exceeding that of the natural photosynthesis in plants (~0.1%). Installing this CNIO-GaSA photocatalytic in a flow system realized a 100% efficiency in bacteria removal, along with excellent stability.

This work provides a novel photocatalyst that enable practical hydrogen peroxide production via two-electron water oxidation.



Hao Tan, Peng Zhou, Meixian Liu, Qinghua Zhang, Fuyang Liu, Hongyu Guo, Yin Zhou, Yan Chen, Lingyou Zeng, Lin Gu, Zhanfeng Zheng, Meiping Tong & Shaojun Guo. Photocatalysis of water into hydrogen peroxide over an atomic Ga-N_5 site. Nature Synthesis, 2023, 2, 557.*

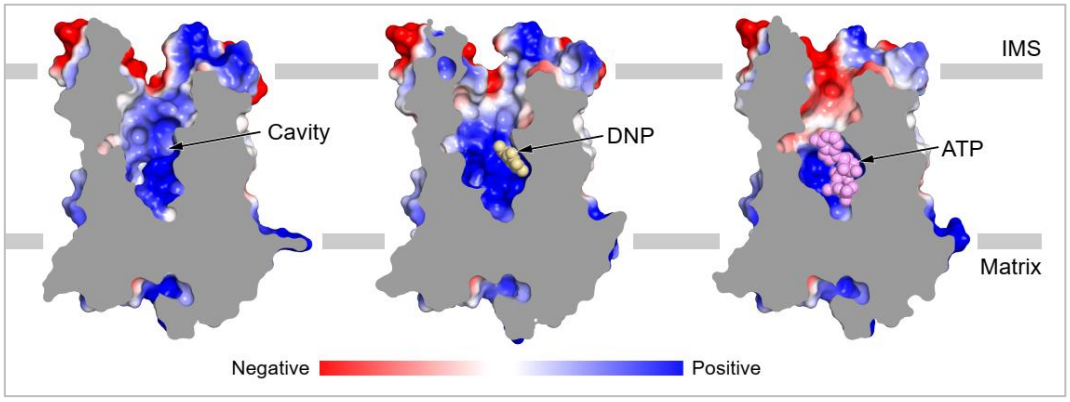
未来技术学院（College of Future Technology）

90．人源产热素与抑制剂和激活剂的结合机制

产热素蛋白 UCP1 对非颤栗产热和维持体温恒定具有重要作用，但其被小分子调控的机制并不清楚。**陈雷研究员团队**解析了人源 UCP1 与抑制剂 ATP 和激活剂 DNP 复合物的结构，阐明了 UCP1 识别小分子的结构机制。

Recognition mechanism of inhibitor and activator by thermogenin

Thermogenin UCP1 is essential for non-shivering thermogenesis and maintaining the body temperature. However, the structure and mechanism of UCP1 remained unknown. **Prof. Lei CHEN**'s group has determined the cryo-EM structures of UCP1 in complex with inhibitor ATP and activator DNP. These structures elucidated how UCP1 recognizes its ligands.



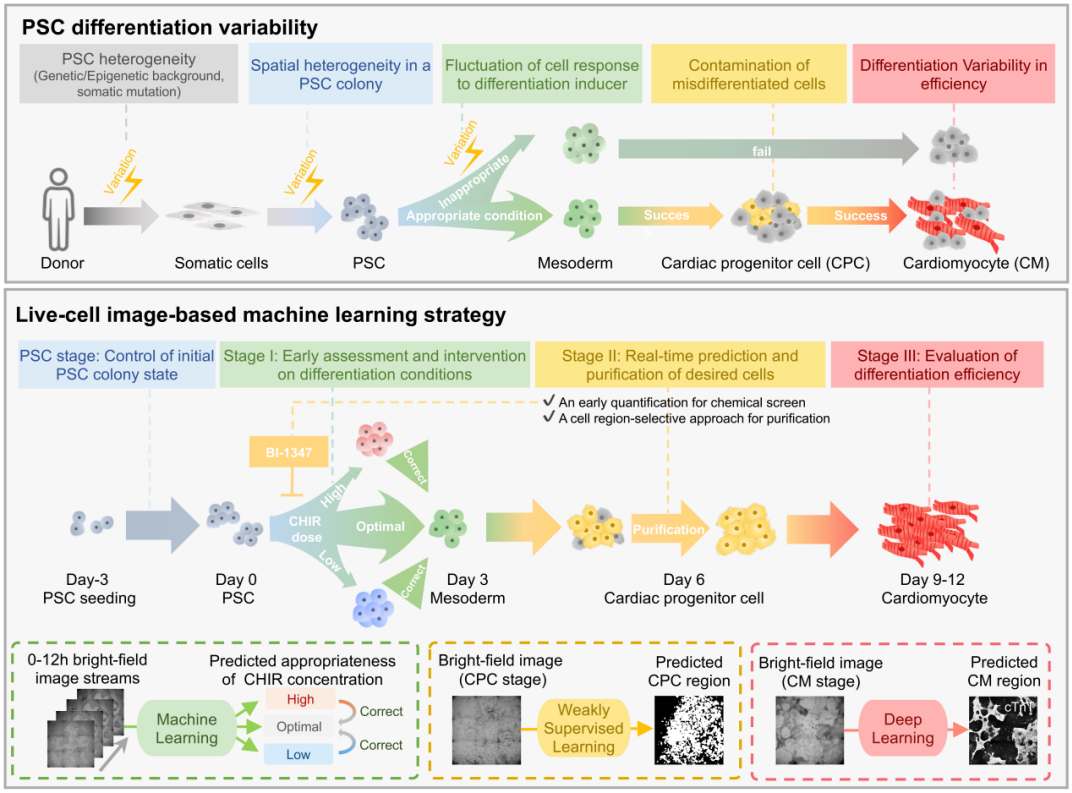
Yunlu Kang and Lei Chen. Structural basis for the binding of DNP and purine nucleotides onto UCP1. in Nature, 2023, 2023/06/20.

91．开发基于细胞动态图像机器学习的 iPSC 向心肌细胞分化智能控制系统

多能干细胞的定向分化效率仍存在细胞系间和批次间的不稳定的问题，严重阻碍了多能干细胞临床应用产品的研发进程及规模化制造。**赵扬研究员项目组**研究开发了一种非侵入式的、基于明场图像和机器学习的策略成功解决了多能干细胞向功能性细胞分化不稳定的问题，实时智能地调节和优化分化过程，实现跨细胞系和跨批次的持续高效分化。这些发现有望为促进高质量多能干细胞产品在再生医学领域里的临床研究及规模化生产提供重要技术基础，为生物医学应用中更好地理解和合理调节功能性细胞的分化过程提供了新的生物学视角。

A live-cell image-based machine learning strategy for reducing variability in PSC differentiation systems

Functional cell differentiation is currently limited by the substantial line-to-line and batch-to-batch variabilities, which severely impede the progress of scientific research and the manufacturing of cell products. In this study, based on live-cell bright-field images, we developed a strategy harnessing different ML models, which can identify cell lineage non-invasively, modulate the differentiation process in real-time, and optimize the differentiation protocol, improving the invulnerability in PSC-to-functional cell differentiation. It also provided a better understanding and rational modulation of the differentiation process for functional cell manufacturing in biomedical applications.



Yang, X., Chen, D., Sun, Q., Wang, Y., Yang, J., Lin, C., Dang, X., Cen, Z., Liang, D., Wei, R., Xu Z., Xi, G., Xue, G., Ye, C., Wang L.-P., Zou, P., Wang, S.-Q., Pablo R.-F., Salome P., Chen, Z., Liu, Y., Zhang. J.*, Zhao, Y.*. A live-cell image-based machine learning strategy for reducing variability in PSC differentiation systems. Cell Discov. doi: 10.1038/s41421-023-00543-1 (2023).*

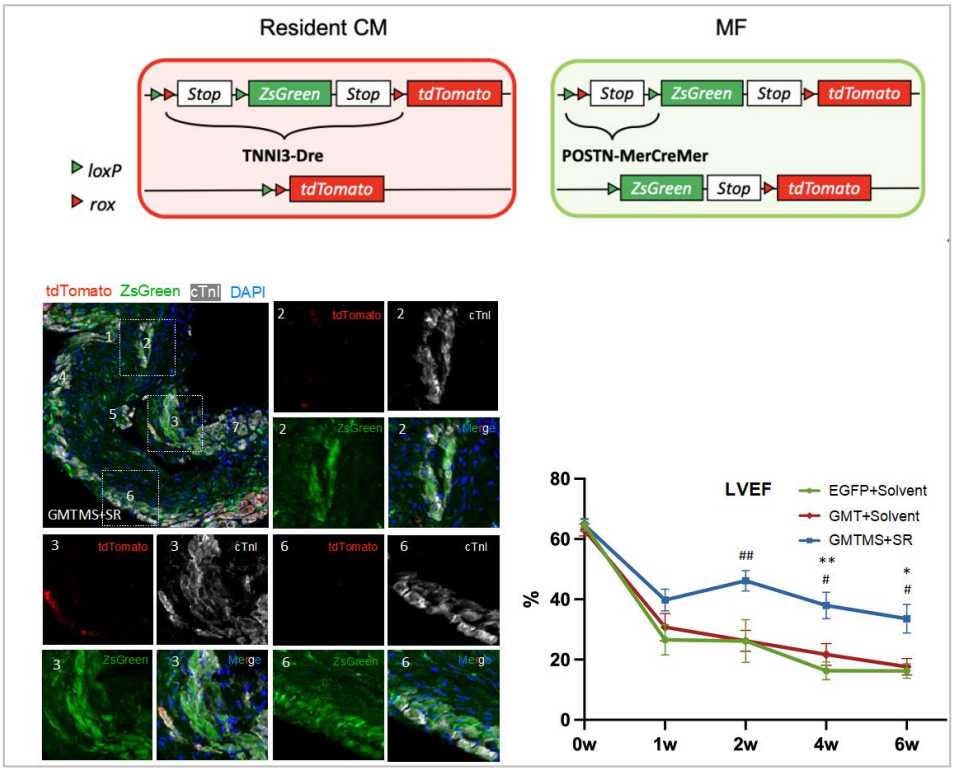
92．利用细胞命运重编程原理实现了高效的心脏再生

如何实现成年哺乳动物心脏再生是一项世界性的科学难题。**赵扬研究员团队**开发了转录因子和化学小分子联用的新重编程组合，在急性心梗模型上成功实现了高效率的肌成纤维细胞向心肌细胞的命运转化，在补充心肌细胞数量的同时延

缓了心脏瘢痕形成。这项研究创新性地使用严格的双重组酶细胞命运示踪系统对该过程进行了观测，解决了原位重编程过程中谱系示踪系统非特异标记内源心肌细胞的问题。这些发现为心脏再生重编程方法的转化应用提供了新的理论基础。

High-efficiency heart cell regeneration through in situ cardiac reprogramming

The heart regeneration in adult mammals is a pivotal scientific challenge. The research team led by **Dr. Yang ZHAO** has developed an enhanced cell reprogramming approach integrating transcription factors and chemical small molecules. They achieved efficient conversion of myofibroblasts into cardiomyocytes within an acute myocardial infarction model, simultaneously replenishing the number of cardiomyocytes and ameliorating the cardiac scarring. This study innovatively introduced stringent dual-recombinase cell fate tracing systems to address the challenge of nonspecific labeling of endogenous cardiomyocytes during in situ reprogramming. These findings provided a new theoretical base for the translational application of reprogramming methods in heart regeneration.



An improved factor combination for in vivo reprogramming of cardiac myofibroblast to cardiomyocyte-like cell with dual recombinase tracing.Wu J#, Zhao H, Tao Y, Yang C, Yang Y, Zhou B, Zhao Y*. Circulation. 2023 Nov 21;148(21):1728-1731. doi: 10.1161/CIRCULATIONAHA.122.062810.*

93．发现了扩张型心肌病的致病机制和治疗方法

程和平院士团队利用转录组、代谢组和表观遗传组等多组学技术手段，证实

线粒体琥珀酸脱氢酶的基因突变是遗传性扩张型心肌病的致病原因，鉴定了该疾病中新的生物标志物琥珀酸，揭示琥珀酸引起心脏基因组的过度甲基化和线粒体脂肪酸代谢失调的分子机制。同时发现 α-酮戊二酸或者高脂肪饮食均可以改善动物的生存时间，缓解心衰的症状，为心肌保护提供了新的治疗策略和干预方法。

Succinate dehydrogenase fine tunes epigenetic and metabolic homeostasis in hearts

Prof. Heping CHENG and his research team from College of Future Technology discovered succinate dehydrogenase (SDH) is required for maintenance of myocardial homeostasis of FAO/glycolysis. Mice with cardiomyocyte-restricted mutation of SDH developed a dilated cardiomyopathy and heart failure and displayed a decrease in FAO, while glucose uptake and glycolysis were augmented, which was reversed by enforcing FAO fuels via a high-fat diet. They found SDH-deficient hearts exhibited an increase in genome-wide DNA methylation associated with accumulation of succinate, resulting in changes of myocardial transcriptomic landscape. Inhibition of succinate by α-ketoglutarate restored transcriptional profiles and metabolic disorders. They revealed the essential role for SDH in metabolic remodeling of failing hearts and highlighted the potential of therapeutic strategies to prevent cardiac dysfunction in the setting of SDH deficiency.

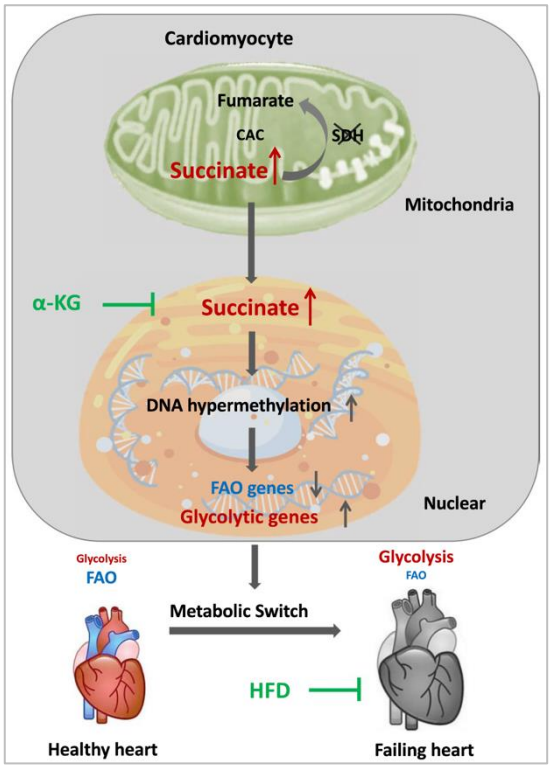


图. 琥珀酸脱氢酶调控心脏功能的模式图。线粒体内膜的琥珀酸脱氢酶突变，可以引起心肌细胞中琥珀酸的累积，诱导细胞核内的表观遗传重塑和甲基化水平增多，导致心脏代谢重编程和心衰。

Figure. Schematic view on succinate-induced epigenetic, metabolic, and cardiac remodeling. SDH ablation in myocardium leads to succinate accumulation which stimulates genome-wide DNA hypermethylation. This epigenetic reprogramming suppresses FAO and induces lipid-to-glucose switch, triggering cardiomyopathy and heart failure. Enforcing FAO fuels via a HFD or inhibition succinate by α-KG protects hearts and increases the viability of mutant animals.

Li W, Quan L, Peng K, Wang Y, Wang X, Chen Q, Cheng H, Ma Q. Succinate dehydrogenase is essential for epigenetic and metabolic homeostasis in hearts. Basic Res Cardiol. 2023 Oct 11;118(1):45.

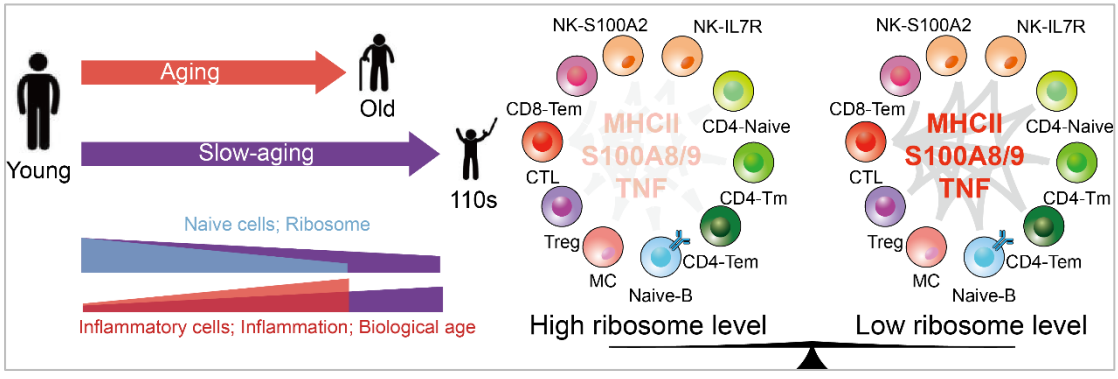
前沿交叉学科研究院（Academy for Advanced Interdisciplinary Studies）

94．基于人类循环免疫系统的单细胞衰老时钟

建立评估个体生理年龄的衰老时钟是现代衰老研究的科学范式，**韩敬东教授课题组**与合作者建立了人类连续衰老过程的循环免疫单细胞图谱，提出了第一个具有高准确性，高健康解释性，可拓展性的人类单细胞衰老时钟，能够精细评估样本的衰老状态和健康状态，并揭示了核糖体水平负调控炎症水平的平衡在衰老和健康长寿过程中的重要作用。

Single-cell aging clock based on human circulating immune system

Establishing an aging clock to assess an individual's biological age represents a scientific paradigm in aging research. The research group led by **Prof. Jingdong Jackie HAN**, in collaboration with other researchers, has developed a cyclical immune single-cell atlas of the continuous aging process in humans. They have introduced the first human single-cell aging clock characterized by high accuracy, interpretability, and scalability. This innovative clock enables a precise evaluation of the aging and health status of samples, revealing the crucial role of ribosomal-level negative regulation in balancing inflammation levels during the aging and healthy longevity processes.



Human PBMC scRNA-seq-based aging clocks reveal ribosome to inflammation balance as a single-cell aging hallmark and super longevity. Zhu H, Chen J, Liu K, Gao L, Wu H, Ma L, Zhou J, Liu Z, Han JJ. Science Advances. 2023 Jun 28;9(26):eabq7599.

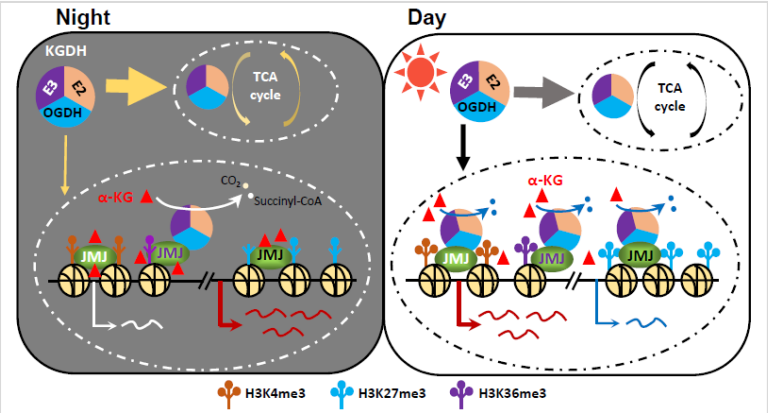
现代农学院 (School of Advanced Agricultural Sciences)

95．核定位α-酮戊二酸脱氢酶复合体调控组蛋白去甲基化及基因表达的分子机理解析

在真核生物中，组蛋白甲基化修饰在调控染色质结构、基因转录和其它染色质相关的过程中起着重要作用，进化保守的含有 Jumonji C 结构域的去甲基化酶家族(Jumonji C-containing histone demethylases，JMJs) 是真核生物中的主要组蛋白去甲基化酶。JMJs 利用 α-酮戊二酸 (α-ketoglutarate，α-KG) 和氧分子作为辅助底物，通过氧化脱羧反应去除组蛋白赖氨酸残基上的甲基化修饰基团。**何跃辉教授团队**发现三羧酸循环的限速酶 α-酮戊二酸脱氢酶复合体 (α-ketoglutarate dehydrogenase，KGDH）响应光信号进入细胞核，并与多种 JMJ 去甲基化酶互作；KGDH 通过竞争性代谢细胞核内的 α-酮戊二酸，抑制了 JMJ 的组蛋白去甲基化活性，从而在全基因组水平调控组蛋白的甲基化修饰进而调控一系列植物环境响应基因表达的分子机理。

Control of histone demethylation and gene expression by nuclear-localized α-ketoglutarate dehydrogenase

Methylations on nucleosomal histones play fundamental roles in the regulation of eukaryotic transcription. The evolutionarily-conserved Jumonji C-domain-containing histone demethylases (JMJs) dynamically control the level of histone methylations in eukaryotes. Using the model plant *Arabidopsis thaliana*, **Prof. Yuehui HE**'s team found that the tricarboxylic acid-cycle-associated enzyme, α-ketoglutarate (α-KG) dehydrogenase (KGDH), enters into the nucleus. Within the nucleus, KGDH interacts with various JMJs to regulate α-KG-dependent histone demethylations. They further show that the nuclear targeting of KGDH is regulated by environmental signals such as light, and that this enzyme complex binds to thousands of loci in the Arabidopsis genome. The chromatin-bound KGDH catalyzes α-KG decarboxylation and thus may limit its local availability to KGDH-coupled JMJs, which inhibits histone demethylation and thus regulates target gene expression in plants and likely in other eukaryotes.



Control of histone demethylation by nuclear-localized α-ketoglutarate dehydrogenase. Huang F, Luo X, Ou Y, Gao Z, Tang

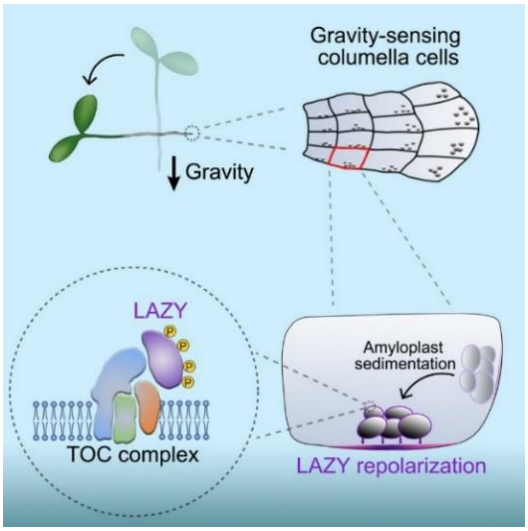
Q, Chu Z, Zhu X & He Y. Science 381: eadf8822 (2023).

96．揭示了植物重力响应的分子机制

重力影响地球上的一切，然而生物如何感知重力一直备受关注。120 年前提出的“淀粉-平衡石”假说认为植物中含有淀粉体的平衡细胞是感受重力的细胞，淀粉体的沉降起始植物的重力感受，然而淀粉体在重力感受中的关键作用一直没有得到证明。该工作揭示了淀粉体在向重力沉降过程中通过表面的 TOC 蛋白携带并指导 LAZY 蛋白形成新的极性分布，进而为植物“指明”重力的方向，调控向性生长。该结果首次完整解析了重力信号是如何转变为植物体内的生理生化信号，为 120 年的未解之谜提供了答案。该项工作发表于学术期刊《Cell》，被评价为“植物重力感应领域具有里程碑意义的工作”。

Mechanism of how plant senses gravity

Gravity affects everything. Understanding how living organisms sense gravity is a widely studied scientific question. The "starch-statolith" hypothesis, proposed 120 years ago, suggested that the sedimentation of starch bodies (amyloplasts) in specific plant cells could initiate gravity perception, yet its underlying mechanism remained unknown for a long time. This study reveals that during the process of amyloplasts sedimentation, the TOC proteins on their surface can carry and guide LAZY proteins to form a new polarity distribution on the cell membrane, thereby regulating the directional growth of plants. Consequently, this research deciphers the key mechanism by which gravity, as a physical signal, transforms into physiological and biochemical signals within plants, unraveling a mystery that persisted for 120 years. The findings have been published in the academic journal "Cell" and are acclaimed as a "milestone work in the field of plant gravity sensing."



Amyloplast sedimentation repolarizes LAZYs to achieve gravity sensing in plants, Chen J., Yu R., Li N., Deng Z., Zhang X., Zhao Y., Qu C., Yuan Y., Pan Z., Zhou Y., Li K., Wang J., Chen Z., Wang XY., Wang XL., He S., Dong J., Deng XW., Chen H., Cell 186(22), 4788-4802 (2023).

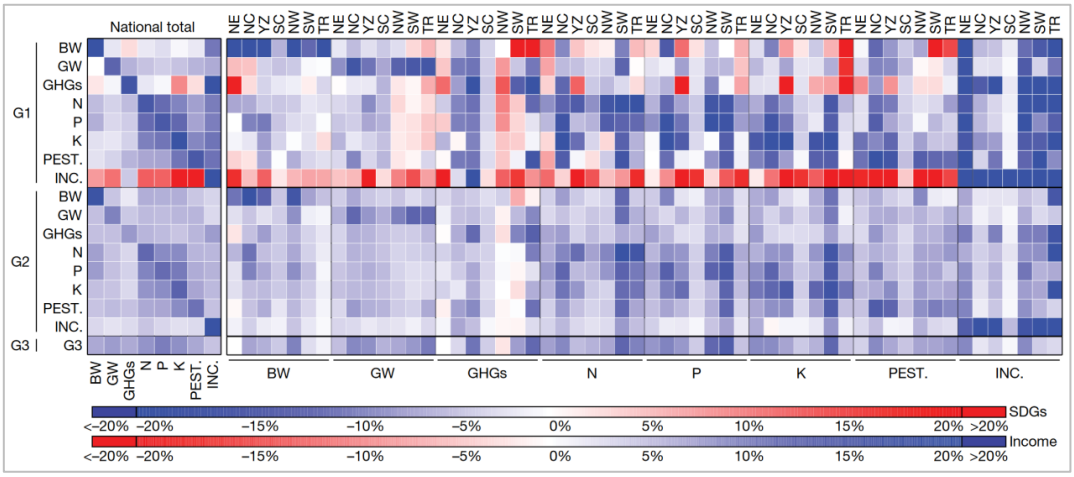
97．农业生产优化布局有潜力促进食物系统可持续发展

形成同资源环境承载力相匹配的现代农业生产区域布局，对保障粮食安全能起到事半功倍的效果。**解伟研究员团队**创新性地研发了空间分辨率高、资源环境

维度高的大型农业生产布局优化模型，证实了当前中国农业生产布局并不合理，多情景模拟回答了农业生产优化布局有潜力跨部门、多资源协同促进食物系统可持续发展，提出未来农业生产布局新方向，为农业适应气候变化提供了新路径。

Crop switching has the potential to promote sustainable development of the food system

It is a crucial part of ensuring food security to establish an optimal agriculture distribution that is commensurate with the bearing capacities of resources and the environment. **Prof. Wei XIE**'s team innovatively develops a large-scale crop switching model with high spatial resolution and multiple sustainability dimensions. They demonstrate that the current crop distribution in China is not optimal, elaborate that crop switching can enhance environmental sustainability and farmer incomes. This work finds a new direction of crop switching and provides a new path for agriculture to adapt to climate change.



Crop switching can enhance environmental sustainability and farmer incomes in China. W. Xie, A. Zhu, T. Ali, Z. Zhang, X. Chen, F. Wu, J. Huang, K. F. Davis. Nature 616, 300-305 (2023).

98．安全程度高的草地使用权有效提高草地质量

草地产权/使用权私人所有还是集体行动更有效一直都很有争议。**侯玲玲研究员团队**与合作者构建了包括草地产权制度改革和草地质量等大规模综合数据集，首次揭示了草地产权制度对草原质量的影响取决于草地使用权私有的安全程度，即物质（如围栏）或法律保障（如使用权证书）可以显著提高草地质量，还揭示了非正式制度（村规民约等）在正式制度（草地使用权确权颁证）完善的情况下也会发挥作用。

Enhanced privatization of grassland use rights increases grassland quality.

The debate over whether private or collective ownership is more effective for grassland property/use rights continues. **Lingling HOU**'s study is the first to

reveal that the impact of grassland property rights on grassland quality depends on the security of privately owned usage rights. Physical measures (like fencing) or legal safeguards (such as usage certificates) significantly enhance grassland quality. The study also shows that informal institutions (e.g. village agreements) play a role even when formal institutes (e.g. certification of grassland use rights) are well-established.

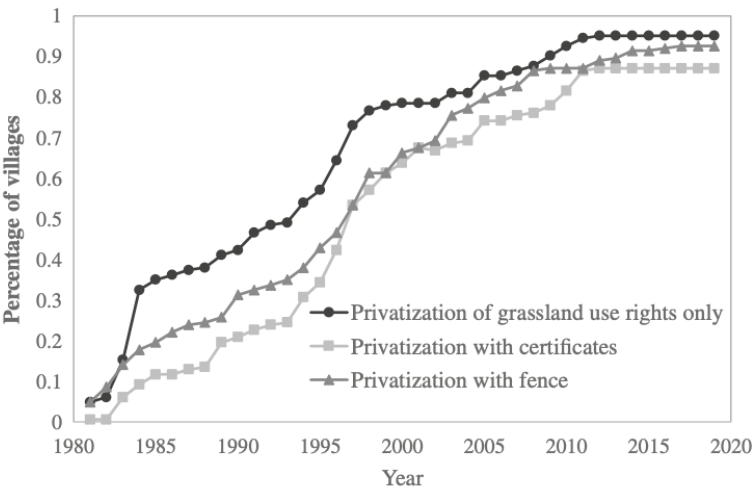


FIGURE 1 Evolution of grassland tenure reform

Hou, Lingling, Pengfei Liu, and Xiaohui Tian. "Grassland tenure reform and grassland quality in China." American Journal of Agricultural Economics 105.5 (2023): 1388-1404.

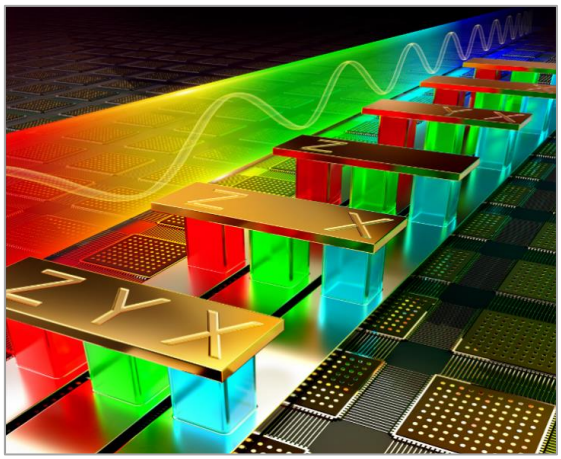
人工智能研究院（Institute for Artificial Intelligence）

99．提出存内计算全谱概念

近年来，存内计算技术得到了学术界、工业界的广泛关注与大量研究投入。**孙仲研究员**联合国内外专家学者提出存内计算技术全谱概念，对所有类型存内计算技术进行了原理性分类，从而为比较每种不同技术的性能提供了一个平台，同时有望启发新型的存内计算技术。

Proposing a full spectrum of computing-in-memory technologies

Recently, computing-in-memory (CIM) technologies have received widespread attention and substantial research investment from both academia and industry. **Zhong SUN,** an assistant professor at Peking University, together with a group of outstanding experts from China, Israel and UK, proposed the concept of a full spectrum of CIM technology, which made a principled classification of all types of CIM technologies. This concept provides a platform for comparing the performance of each different technology and is expected to inspire new types of CIM technologies.



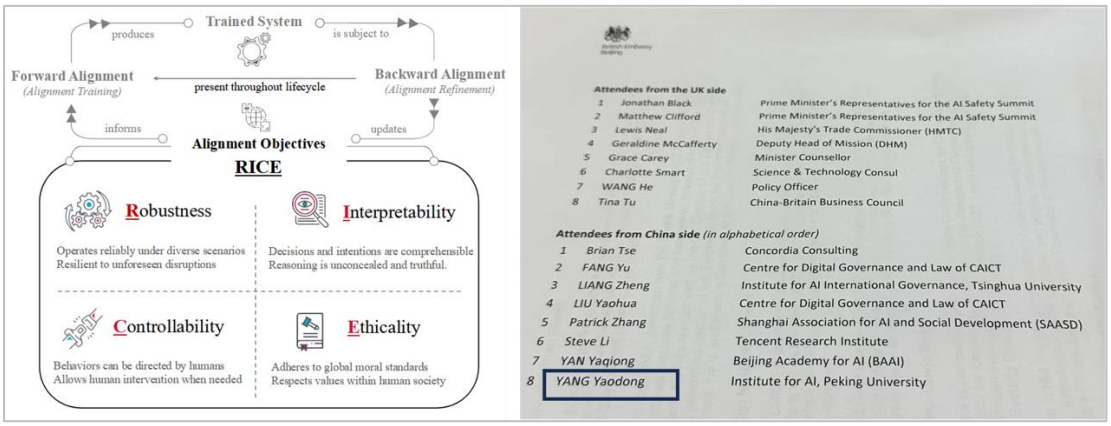
Z. Sun, S. Kvatinsky, X. Si, A. Mehonic, Y. Cai, R. Huang. A full spectrum of computing-in-memory technologies. Nat. Electron. 6, 823-835 (2023).*

100．开源国内首个可复现的安全对齐框架，参与布莱切利宣言闭门研讨会

在通用人工智能技术迈入关键发展阶段之际，确保其与人类社会价值观的安全对齐显得尤为重要。**杨耀东助理教授课题组**在 AI 对齐领域取得了突破性进展，开源了国内首个针对大型语言模型的安全对齐框架，并发布了业内首个 AI 对齐全面性综述，其参与对齐的 Baichuan2 开源模型获得了网信办首批的 8 个牌照，为我国大语言模型的安全对齐技术做出了贡献。十月，杨耀东老师作为学术界代表参加了由英首相特使主办的《布莱切利宣言》中国闭门研讨会，就安全对齐议题发出了中国学者的独到见解和贡献。

The First Open-Source Safe RLHF Framework for Large Language Models, Participating in the closed-door Round Table Discussion for Bletchley Declaration.

As the development of general artificial intelligence (AGI) technology enters a critical phase, ensuring its safety alignment with human values becomes particularly important. **Yaodong YANG**'s team has made significant progress in this field, having open-sourced the first domestic framework for the safety alignment of large language models (LLM), providing strong support for research in the safety and value alignment of LLMs. Additionally, as a representative of the academic community, YANG YAODONG participated in the closed-door pre-symposium of the Bletchley Declaration in China. During the meeting, he engaged in in-depth discussions with the special envoy of the British Prime Minister and domestic safety governance experts, effectively conveying the unique insights and contributions of Chinese scholars on the safety development of AGI.

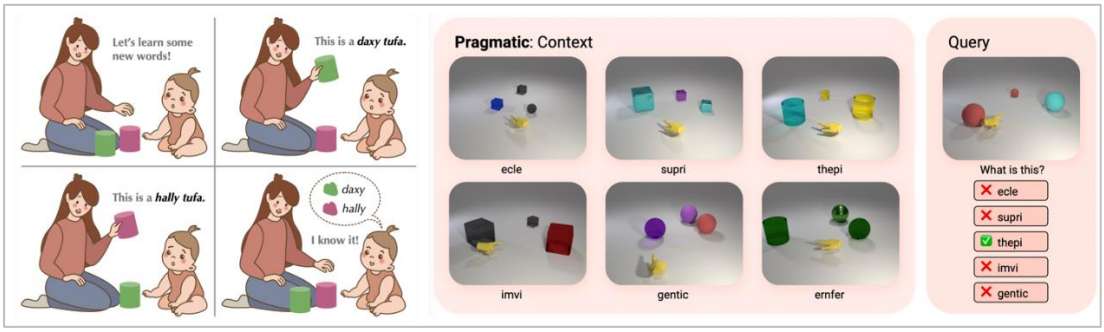


101．在支持机器进行词汇学习和更广泛的人类学习上取得进展

单词学习被认为是多模态理解和推理最基本的基石。受到儿童少样本单词学习能力的启发，**朱毅鑫助理教授**团队构建了 MEWL 基准来指导机器在视觉场景中学习单词和概念，为多模态通用人工智能的评估提供了新的方向。

Few-shot multimodal word learning with referential uncertainty

Word learning is believed to be one of the most fundamental building blocks of multimodal understanding and reasoning. Motivated by the capability that young children can understand a novel word's meaning merely from a few examples, **Prof. Yixin ZHU** and his team developed the MEWL (MachinE Word Learning) benchmark suite to evaluate and guide machine word learning in grounded visual scenes, demonstrating a new approach for the evaluation of multimodal artificial general intelligence.



Jiang, G., Xu, M., Xin, S., Liang, W., Peng, Y., Zhang, C. & Zhu, Y. (2023). MEWL: Few-shot multimodal word learning with referential uncertainty. Proceedings of the 40th International Conference on Machine Learning, in Proceedings of Machine Learning Research, 202:15144-15169.

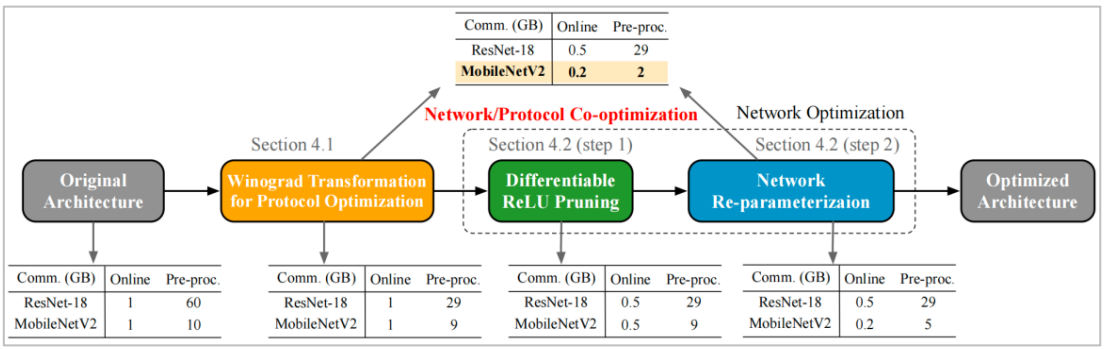
102．提出基于 Winograd 的高效神经网络隐私推理

李萌教授团队提出了一个隐私推理协议和深度神经网络架构协同优化的框架。该团队提出了一种新颖的基于 Winograd 变换的安全卷积协议以及一系列神

经网络感知的优化，以显著降低推理开销。该团队进一步提出了隐私推理通信感知的神经网络优化算法，该算法与所提出的协议相兼容。该框架同时降低了预处理阶段和在线阶段的通信开销，也降低了所有线性和非线性操作的通信开销。

Network/Protocol Co-Optimization for Communication-Efficient Private Inference

Prof. Meng LI and his research team proposed a co-optimization framework for both privacy inference protocols and deep neural network architectures. His team proposed a new secure convolutional protocol based on the Winograd transformation as well as a series of neural network-aware optimizations to dramatically reduce the communication overhead. His team further proposed a inference communication-aware network optimization algorithm, which is compatible with the proposed protocols. The co-optimization framework can simultaneously reduce the communication overhead for pre-processing stage, online stage, linear operations, and non-linear operations.



Wenxuan Zeng, Meng Li, Haichuan Yang, Wen-jie Lu, Runsheng Wang, Ru Huang. CoPriv: Network/Protocol Co-Optimization for Communication-Efficient Private Inference. Thirty-seventh Conference on Neural Information Processing Systems (NeurIPS 2023).

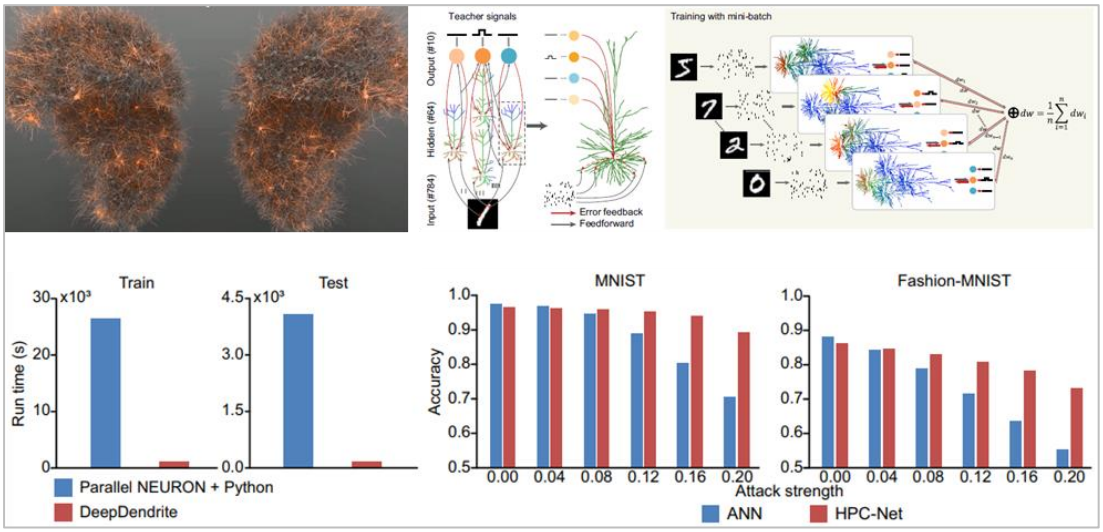
103．新一代基于 GPU 的大脑模拟框架 DeepDendrite

高昂的计算代价是对大脑进行精细模拟的核心挑战。**杜凯助理研究员团队**提出了仿真精细神经元理论效率最优的“树突层级调度算法”，并开发了基于 GPU 平台的大规模精细神经网络仿真加速框架 DeepDendrite，其仿真速度相比主流框架 NERUON 提升 2 到 3 个数量级，并且实现了领域内第一个基于精细神经元模型的人工神经网络，为构建更接近人脑的通用智能铺平了道路。

DeepDendrite: A New Generation GPU-Based Brain Simulation Framework

The primary challenge in detailed brain simulation is the high computational cost. Prof. Du Kai and his team proposed the "Dendritic Hierarchical Scheduling Algorithm," optimized for efficiently simulating detailed neuronal theories. They developed DeepDendrite, a GPU-based framework for accelerating large-scale,

detailed neural network simulations. This framework significantly outperforms the mainstream NEURON framework, achieving simulation speeds 2 to 3 orders of magnitude faster. It also pioneered the first artificial neural network based on detailed neuron models in the field, laying the groundwork for building more brain-like general intelligence.



Zhang, Y., He, G., Ma, L. et al. A GPU-based computational framework that bridges neuron simulation and artificial intelligence. Nat Commun 14, 5798 (2023).