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《科学》（20260521出版）一周论文导读。编译李言

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物理Physics

Dynamics of disordered quantum systems with two- and three-dimensional tensor networks

二维与三维张量网络下无序量子系统的动力学

作者：Joseph Tindall, Antonio Francesco Mello, Matthew Fishman et al.

链接：

<https://www.science.org/doi/10.1126/science.adx2728>

摘要：

近期，D-Wave公司的Advantage2系统在多种晶格上实现了伊辛自旋玻璃的大规模量子退火动力学实验。经过与现有数值方法的广泛比较，这些实验被宣称超越了经典计算的能力范围。

研究者采用特定晶格张量网络对上述自旋玻璃模型进行模拟，利用置信传播算法跟踪时间演化中产生的纠缠，并借助更先进的置信传播变体提取期望值。

研究者发现，仅使用适中的计算资源即可达到当前最优精度。此外，研究者的模拟方法在二维和三维空间均具有可扩展性，并借此在包含数百量子比特的系统中验证了基布尔—祖雷克普适物理。

Abstract：

Large-scale quantum annealing dynamics of Ising spin glasses were recently implemented on D-Wave's Advantage2 system on a range of lattices. After extensive comparison with existing numerical methods, these experiments were claimed to be beyond the reach of classical computation. Here, we simulated these spin-glass models with lattice-specific tensor networks, using belief propagation (BP) to keep up with the entanglement generated during the time evolution and then extracting expectation values with more sophisticated variants of BP. We found that state-of-the-art accuracies could be achieved with modest computational resources. Moreover, our results are scalable in both two and three dimensions, which we leveraged to verify universal Kibble-Zurek physics on systems involving hundreds of qubits.

材料科学 Materials Science

Device-scaling constraints imposed by the van der Waals gap formed in two-dimensional materials

二维材料中范德华间隙对器件尺寸缩放的制约

作者：Mahdi Pourfath and Tibor Grasser

链接：

<https://www.science.org/doi/10.1126/science.aeb2271>

摘要：

晶体管的小型化要求通过超薄电介质控制栅极泄漏，并最小化源漏接触电阻。

尽管二维半导体具有优异的静电控制能力，但它们与栅介质和接触金属的界面往往会形成范德华间隙，这一间隙不仅影响器件性能，同时作为一个低介电常数的隧穿势垒发挥作用。

虽然范德华间隙降低了介电泄漏，但它增加了金属—沟道接触电阻，并向栅极引入寄生串联电容。

研究者量化了泄漏抑制与静电及接触电阻缩放极限之间的权衡关系。由于这种权衡的存在，许多绝缘体无法满足缩放目标，金属—沟道接触也难以达到所需的电阻值。类似拉链的界面（准共价键消除范德华间隙而不产生悬挂键）为实现超大规模晶体管设计提供了一条路径。

Abstract :

Transistor miniaturization requires controlling gate leakage through ultrathin dielectrics and minimizing source-drain contact resistance. Although two-dimensional semiconductors offer excellent electrostatic control, their interfaces with gate dielectrics and contact metals often form a van der Waals (vdW) gap that affects device performance and acts as a tunneling barrier with a low dielectric constant. While this reduces dielectric leakage, it increases metal-channel contact resistance and introduces a parasitic series capacitance to the gate. We quantified the trade-off between leakage suppression and electrostatic and contact-resistance scaling limits. As a result of this trade-off, many insulators fail to meet scaling targets, and metal-channel contacts fall short of required resistances. Zipper-like interfaces, where quasi-covalent bonding removes the vdW gap without creating dangling bonds, offer a path toward ultrascaled transistor designs.

动物学Zoology

Reward magnitude determines reinforcement learning efficiency

奖励幅度决定强化学习效率

作者：Sheng Gong, Alyssa Martell, Joshua T. Dudman, and Luke T. Coddington

链接：

<https://www.science.org/doi/10.1126/science.aeb0813>

摘要：

标准动物学习研究通过最小化单次奖励幅度来最大化强化行为的重复次数。研究者通过五种行为范式的初生小鼠探讨了，奖励幅度如何影响初始学习。大额奖励可通过其对会话内学习、跨会话学习及任务参与度的分离效应，显著提升学习效率。

腹侧纹状体多巴胺释放的持续时间与幅度随奖励大小呈比例变化，而通过光遗传学延长多巴胺奖励响应也复现了大额奖励带来的大部分（但非全部）学习收益。

这些发现表明，动物的强化学习效率在传统研究中被低估了；同时，多巴胺对奖励的信号传导以与绝对奖励幅度成比例的方式调节任务参与度。

Abstract :

Standard animal learning studies minimize individual reward magnitudes to maximize the repetitions of reinforced behaviors. We investigated how reward magnitude influences initial learning across five behavioral paradigms in naïve mice. Especially large rewards could substantially improve learning efficiency through dissociable effects on within- and across-session learning and task engagement. The duration and magnitude of ventral striatal dopamine release scaled with reward sizes, and prolonged optogenetic enhancement of dopamine reward responses also reproduced much, but not all, of the benefits to learning produced by outsized rewards. These findings indicate that the reinforcement learning efficiency of animals has traditionally been underestimated and that dopamine signaling of rewards mediates task engagement in proportion to absolute reward magnitude.

古人类学Paleoanthropology

Long-distance genetic relatedness in megalithic central Europe

中欧巨石文化社会中的远距离遗传亲缘关系

作者：Nicolas Antonio da Silva, Almut Nebel, Daniel Kolbe et al.

链接：

<https://www.science.org/doi/10.1126/science.aeb2926>

摘要：

新石器时代晚期的欧洲巨石建筑常被视为共同祖先的象征。研究者分析了与西部漏斗颈陶文化和瓦特贝格文化群体相关的六个巨石墓群中203个个体的全基因组数据。尽管考古学上被视为不同群体，但结果显示这两个群体的个体构成了遗传上同质的人群。

此外，研究者发现了跨越225公里的第一和第二等级亲属关系，揭示了出乎意料的远距离联系以及持续的遗址间和群体间流动性。

这六个墓群作为公共墓地发挥作用，并非仅供近亲使用，表明社会亲缘关系在其中扮演了重要角色。与欧洲其他地区巨石人群遗传联系的有限证据表明，巨石建筑是通过文化传播而非生物网络扩散的。

Abstract :

Megalithic monuments in Late Neolithic Europe are often viewed as symbols of shared ancestry. In this study, we analyzed genome-wide data of 203 individuals buried in six megalithic grave complexes associated

with the Western Funnel Beaker and Wartberg groups. Despite being considered archaeologically distinct, our results show that the studied individuals from both groups form a genetically homogeneous population. Moreover, we identified first- and second-degree relationships spanning up to 225 km, revealing unexpectedly long-distance ties and sustained intersite and intergroup mobility. The six grave complexes functioned as communal burial grounds and were not exclusively used for close genetic relatives, indicating that social kinship played an important role. Limited evidence for genetic connections to distant European megalithic populations indicates that monumentality spread culturally rather than through biological networks.

生态学Ecology

Interacting effects of human presence and landscape modification on birds and mammals

人类存在与景观改造对鸟类和哺乳动物的交互影响

作者：Ruth Y. Oliver, Scott W. Yanco et al.

链接：

<https://www.science.org/doi/10.1126/science.adq3396>

摘要：

研究者利用移动设备数据，揭示了人类存在与景观改造对美国37种哺乳动物和鸟类地理与生态环境空间利用的差异化影响。人类存在影响了超过65%的物种，且影响程度在不同物种间存在显著差异。

在对人类活动有响应的物种中，约60%的物种效应表现为相互依存——即在景观改造程度较低的生境中，动物对人类存在的反应更为强烈。

研究结果表明，人类存在与景观改造对野生动物具有复杂的交互效应，有效的管理策略需将二者纳入考量。

Abstract：

Here, we leverage mobile-device data to disentangle how human presence and landscape modification differentially influence the use of geographic and environmental space for 37 mammal and bird species across the United States. Human presence affected more than 65% of species, with substantial variation across species. For ~60% of species that responded to human activities, the effects were interdependent—animals tended to react more strongly to human presence in less modified habitats. Our results demonstrate that human presence and landscape modification have complex combined effects on wildlife, which need to be considered for effective management.

天文学Astronomy

Cloudy mornings and clear evenings on a gas giant exoplanet

气态巨行星系外行星上的多云早晨和晴朗夜晚

作者：Sagnick Mukherjee, David K. Sing et al.

链接：

<https://www.science.org/doi/10.1126/science.adx5903>

摘要：

系外行星大气光谱受来源不确定的气溶胶（云和霾）影响。此前研究提出的气溶胶形成机制包括气体凝结或光化学反应。研究者测量了潮汐锁定的气态巨行星WASP-94A b的透射光谱，并识别出其大气的不对称性：清晨较冷且多云，而夜晚较热并呈现气态水吸收特征。

研究者将这种差异解释为清晨侧附近云滴的形成，在环流输送到黄昏侧时蒸发。主导的气溶胶是在大气昼夜侧之间循环的云，而非光化学霾。由此产生的不对称性可能严重偏差化学丰度测量结果，除非进行分临边光谱观测。

Abstract：

The spectra of exoplanet atmospheres are affected by aerosols (clouds and hazes) of uncertain origin. Proposed aerosol formation mechanisms include gas condensation or photochemical reactions. We measured the transmission spectrum of the tidally locked gas giant exoplanet WASP-94A b and identified asymmetry in its atmosphere. The morning limb is cooler and cloudy, whereas the evening limb is hotter and exhibits gaseous water absorption features. We interpret this difference as being due to the formation of cloud droplets near the morning limb, which evaporate during circulation to the evening limb. The dominant aerosols are clouds cycling between the day and night sides of the atmosphere, not photochemical hazes. The resulting asymmetry can severely bias chemical abundance measurements, unless limb-resolved spectroscopy is available.

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