《自然》（20260618出版）一周论文导读

作者：writer 来源：科学网

本文原地址：https://www.iikx.com/news/progress/40471.html

《自然》（20260618出版）一周论文导读。编译｜未玖

Nature, 18 June 2026, Volume 654, Issue 8119

《自然》，2026年6月18日，第654卷，8119期

天文学Astronomy

A distant brown dwarf coplanar to a warm Jupiter and a hot super-Earth

一颗与温暖木星和炽热超级地球共面的遥远褐矮星

▲ 作者：Mat í as I. Jones, Luca Naponiello, Trifon Trifonov, Rafael Brahm, Gabriele Pichierri, Lorena Acu?a-Aguirre, et al.

▲链接：

https://www.nature.com/articles/s41586-026-10586-5

▲摘要：

在凌星行星系统中，行星大小可通过凌星观测精确测定，而凌星时间变化（TTVs）的存在，尤其是当与视向速度（RV）数据相结合时，可为行星质量和轨道离心率提供强有力的约束。

这些测量结果共同为理解行星系统的结构、形成机制及动力学演化提供了关键见解。

研究组展示了对相对年轻的恒星（年龄约为10亿年）TOI-201的长期RV及凌星/TTV监测结果，揭示了一个特殊的多行星系统。

该系统由一颗每5.8天凌星一次的炽热超级地球（SE）大小的行星、一颗轨道周期为53天的温暖木星（WJ），以及一颗轨道周期约为8年、离心率较高（e=0.62）的低质量褐矮星（BD）组成，后者的质量（MBD）约为16倍木星质量。

该BD是迄今为止通过RV手段表征的轨道周期最长的凌星亚恒星天体，也是已知唯一与内侧行星共面的此类天体。

该系统的结构表明，这颗SE是在气态盘最内部区域孤立形成的。另一方面，外侧伴星的轨道构型表明这两个天体几乎是在原位形成的，其中WJ形成于致密的内部盘区。

另一种可能是，这颗BD可能在更远处形成，随后向内迁移，并在与星盘相互作用的过程中增加了其轨道离心率。

▲ Abstract：

In transiting planetary systems, in which planetary sizes are accurately determined from transit observations, the presence of transit-timing variations (TTVs), especially when combined with radial velocity (RV) data, provides powerful constraints on masses and orbital eccentricities. Together, these measurements offer crucial insights into system architecture, formation mechanisms and dynamical evolution. We present long-term RV and transit/TTV monitoring of the relatively young star (age approximately 1 Gyr) TOI-201, revealing an exceptional multi-planet system composed of a hot super-Earth (SE) size planet transiting every 5.8 days, a warm Jupiter (WJ) on a 53-day orbit and an eccentric (e=0.62) low-mass brown dwarf (BD) on an approximately 8-year orbit, with an estimated mass MBD of about 16 Jupiter masses. The BD is the longest-period transiting substellar object ever characterized by means of RVs and the only one known to be coplanar with inner planets. The architecture of this system suggests that the SE was formed isolated and in the innermost region of the gaseous disk. On the other hand, the orbital configuration of the outer companions suggests a nearly in situ formation of both objects, with the WJ forming in a dense inner disk. Alternatively, the BD might have formed farther out and migrated inward, while increasing its eccentricity owing to interactions with the disk.

物理学Physics

Nuclear shell structure governs short-range nucleon pairing

核壳结构支配短程核子配对

▲ 作者：D. Nguyen, C. Yero, H. Szumila-Vance, F. Hauenstein, N. Swan, L. B. Weinstein, et al.

▲链接：

https://www.nature.com/articles/s41586-026-10616-2

▲摘要：

原子核是一种结构复杂的量子体系，核子（质子与中子）依靠强核力束缚在一起。在极近距离下，核子能够瞬时形成高动量配对（即短程关联对），促成核物质的高动量结构。研究核子如何形成短程关联对，为探究强相互作用的短程行为提供了罕见的实验窗口。

研究组选取具有独特壳层结构的40Ca、48Ca和54Fe原子核，利用高能电子散射实验探测短程关联对的形成规律。

出乎意料的是，研究组发现短程关联配对行为更多取决于质子和中子所占据的特定量子轨道，而非原子核质量或中子-质子失衡程度。该依赖性远高于现有理论模型的预测值。

该结果表明，支配短程核子配对的角动量量子选择规则需重新建立，同时揭示了长程原子核壳结构与短程相互作用之间存在深层内在关联。

▲ Abstract：

Atomic nuclei are intricate quantum systems in which nucleons (protons and neutrons) are held together by the strong nuclear force. At very short distances, nucleons can momentarily form high-momentum pairs—known as short-range-correlated pairs—that shape the high-momentum structure of nuclear matter. Studying how nucleons form short-range-correlated pairs provides a rare experimental window into the short-distance behaviour of the strong interaction. Here we use the scattering of high-energy electrons from 40Ca, 48Ca and 54Fe, chosen for their distinct shell structures, to probe the formation of short-range-correlated pairs. Unexpectedly, we find that short-range-correlated pairing depends far more on the specific quantum orbitals occupied by protons and neutrons than on the nuclear mass or neutron − proton imbalance. This dependence is much stronger than that predicted by theoretical models. Our results point to a need for new angular-momentum quantum selection rules governing short-range nucleon pairing and reveal a deep connection between long-range nuclear shell structure and short-range interactions.

Two-component exciton condensates in an electron – hole bilayer

电子-空穴双层中的双组分激子凝聚

▲ 作者：Ruishi Qi, Qize Li, Jiahui Nie, Ruichen Xia, Haleem Kim, Hyungbin Lim, et al.

▲链接：

https://www.nature.com/articles/s41586-026-10636-y

▲摘要：

玻色子凝聚形成玻色-爱因斯坦凝聚体（BEC）时，会产生宏观量子相干效应。激子是人们长期探寻、可在固态体系中实现高温BEC的理想载体，兼具强相互作用、电可调特性以及潜在的多组分旋量有序，但激子达到平衡态凝聚的确凿实验证据仍未找到。

研究组通过探测构成激子的电子与空穴的自旋-谷极化率，在MoSe2/hBN/WSe2电子-空穴双层结构中，观测到双组分激子BEC的实验证据。该异质结构可形成具备四种自旋-谷组态的平衡态激子流体。

稀释制冷机中的磁光谱表征揭示了三种具有不同组态极化特征的激子凝聚相：零磁场下，多体基态是两个凝聚谷内激子组态的相干叠加；施加外磁场时，在一个较低临界磁场处，体系会通过一级量子相变，由谷内激子凝聚转变为双组分谷间激子凝聚；磁场进一步升高后，体系最终变为完全极化的单组分凝聚体。

凝聚特征在密度-温度相图中呈现穹顶形相区，最高在约1.8K时可稳定存在。该研究证实，范德华电子-空穴双层结构是研究强相互作用、多组分激子BEC的优良平台。

▲ Abstract：

Macroscopic quantum coherence emerges when bosons condense into a Bose – Einstein condensate (BEC). Excitons are a long-sought solid-state route to high-temperature BECs with strong interactions, electrical tunability and potentially multicomponent spinor order, but conclusive evidence for equilibrium condensation has remained elusive. Here we report evidence for two-component exciton BECs in MoSe2/hBN/WSe2 electron – hole bilayers by probing the spin – valley susceptibility of constituent electrons and holes. This heterostructure hosts equilibrium exciton fluids with four spin – valley flavours. Magneto-optical spectroscopy in a dilution refrigerator reveals three exciton condensate phases with distinct flavour polarizations. At zero magnetic field, the many-body ground state is a coherent superposition of two condensed intravalley exciton flavours. Under a magnetic field, the intravalley exciton condensate first switches to a two-component intervalley condensate through a first-order quantum phase transition at a weak critical field and then turns into a fully polarized single-component condensate at high fields. The condensate signatures form a dome in density – temperature space, persisting up to approximately 1.8 K. Our results establish van der Waals electron – hole bilayers as a versatile platform for strongly interacting, multicomponent exciton BECs.

材料科学Materials Science

Probing picometre-scale interlayer deformations via hyperbolic polaritons

基于双曲极化激元的皮米级层间形变探测

▲ 作者：Shu Zhang, Xiangdong Guo, Xiaowen Zhang, Jiashu Yang, Qinzheng Yu, Zhengyang Mou, et al.

▲链接：

https://www.nature.com/articles/s41586-026-10638-w

▲摘要：

范德华（vdW）材料耐受强应变场的特性，使其成为调控电子、光学与磁学性质的理想研究平台。尽管面内应变的表征手段已较为成熟，但针对面外应变开展无损定量表征仍颇具难度，对于界面处皮米级的微小形变而言更是如此。

研究组提出一种极化激元光学检测方法，利用中红外面外双曲极化激元（oHPs）模型，实现对典型范德华极性绝缘体——六方氮化硼（hBN）层间形变的探测。该方法依托层间应变引发的面外横向光学（oTO）声子软化效应，可高灵敏检测皮米级形变。

这类oTO声子模态在常规光谱中通常属于“暗模”，借助oHPs可激活其应变响应，最终实现约10 pm（约为探测波长的8×10-7倍）的原子位移探测灵敏度，实现超深亚波长尺度的层间力学形变检测。

研究组分别在平面hBN样品和量子点-hBN纳米管异质结的隐埋界面上完成了实验验证。这种基于极化激元的皮米测量技术打通了纳米力学与光子学的交叉研究路径，提供了一种无损表征手段，可实现原子级精度可视化观测隐蔽应力分布场。

▲ Abstract：

The resilience of van der Waals (vdW) materials to large strain fields makes them an ideal platform for tuning electronic, optical and magnetic properties. Although in-plane strain is readily mapped, non-invasive and quantitative characterization of out-of-plane strain remains a formidable challenge, particularly for picometre-scale deformations buried at interfaces. Here we demonstrate a polaritonic optical method that uses the mid-infrared out-of-plane hyperbolic polaritons (oHPs) mode to detect interlayer deformations in prototypical vdW polar insulator – hexagonal boron nitride (hBN). This method uses the softening mechanism of out-of-plane transverse optical (oTO) phonons induced by interlayer strain, enabling highly sensitive detection of picometre-scale deformations. Although these oTO phonon modes are typically spectroscopically ‘dark’, their strain response is activated through the oHPs, achieving an atomic displacement sensitivity of about 10 pm (about 8 × 10-7 times the probing wavelength), enabling ultradeep-subwavelength mechanical interlayer deformation detection. This is experimentally validated in both planar hBN and at the buried interface of quantum dot – hBN nanotube heterostructures. This polariton-based picometrology bridges nanomechanics and photonics, providing a non-destructive lens to visualize hidden stress landscapes with atomic precision.

Stereoelectronic manipulation of ligands for perovskite solar cells

钙钛矿太阳能电池配体的立体电子操纵

▲ 作者：Tinghuan Yang, Erxin Zhao, Nan Wu, Xiaoming Chang, Chenqing Tian, Hai-Long Wang, et al.

▲链接：

https://www.nature.com/articles/s41586-026-10626-0

▲摘要：

钙钛矿/电荷传输层（CTL）异质结处的界面损耗，始终是制约钙钛矿太阳能电池（PSC）实现高性能的关键瓶颈。尽管分子配体能够钝化界面空位缺陷，但其竖直锚定构型会增加界面输运路径，进而阻碍电荷传输。

研究组表明，对配体吸附拓扑结构进行立体电子调控，可实现界面最低能量损耗，从而构筑高效、稳定的PSC。

通过将氮原子战略性地取代苯环碳原子，构建吡啶环或嘧啶环结构，研究组设计出一类新型配体：可通过Pb-N配位键和Pb-I-
π相互作用同时锚定到钙钛矿上，使单一分子具备两种协同结合模式。

这种相互增强的立体电子作用，可驱动配体在热力学上倾向于平面排布，既能在原子尺度实现缺陷减少，又可保证界面处亚纳米尺度的高效电荷转移。

优化的界面架构实现了26.85%的稳定功率输出，经认证的反向扫描和正向扫描效率分别为27.41%和26.35%。此外，该光伏组件表现出优异的运行稳定性，经258天户外实时现场测试后，组件效率仍可维持初始效率的85.8%。

▲ Abstract：

Interfacial losses at perovskite/charge transport layer (CTL) heterojunctions persist as a critical barrier to achieving high-performance perovskite solar cells (PSCs). Although molecular ligands can passivate interfacial vacancy defects, their vertical anchoring geometry compromises charge transport by increasing interfacial transport pathways. Here we demonstrate that stereoelectronic manipulation of ligand adsorption topology advances interfacial minimum energy loss for efficient and stable PSCs. By strategically replacing benzene carbons with nitrogen atoms to create pyridine or pyrimidine rings, we design ligands that concurrently anchor to the perovskite through Pb – N coordination bonds and Pb – I – π interactions, endowing a single molecule with dual, synergistic binding modes. This mutually reinforcing stereoelectronic interplay drives thermodynamically favourable planar alignment of ligands, enabling atomic-scale defect mitigation while maintaining sub-nanometre-scale charge transfer across the interface. The optimized interfacial architecture achieves a stabilized power output of 26.85%, with certificated reverse-scan and forward-scan efficiencies of 27.41% and 26.35%, respectively. Furthermore, the solar modules exhibit exceptional operational stability, retaining 85.8% of initial module efficiency after 258 days of outdoor real-time field testing.

地球科学Earth Science

Earth ’s east – west albedo symmetry

地球东西反照率对称

▲ 作者：Jianhao Zhang, Jake J. Gristey Graham Feingold

▲链接：

https://www.nature.com/articles/s41586-026-10624-2

▲摘要：

地球反照率是行星能量收支的基础要素。北半球与南半球对地球整体反照率的贡献基本均等，这一奇特又难以解释的现象被称为半球反照率对称性。此类对称现象虽较为罕见，却并非地球独有。

但学界未曾探究其他类型的反照率对称性，而这有助于厘清反照率对称的形成机制，及其对行星能量收支的影响。

研究组基于长达25年的卫星观测数据研究发现，地球还存在一种独特且长期稳定的东西半球反照率对称性：以东经27°经线为界划分东、西半球，两个半球反射的太阳辐射总量几乎相等。

与南北半球反照率对称不同，东西半球对称呈现特殊的“三重对称”特征，即晴空反照率、云辐射效应、开阔大洋占比三项指标，均围绕该经线呈现半球对称分布。

东西半球反照率对称的成因在于东半球较强的高云反射与西半球较强的低云反射相互平衡。此外，东西半球反照率对称的年际变化与厄尔尼诺-
南方涛动（ENSO）位相同步，说明该对称特征可能与大气环流存在关联。

东西半球反照率对称及其三重对称性的发现，可为地球系统模型（ESM）提供自由度约束条件，同时凸显在气候快速变化背景下持续开展地球辐射收支观测的重要意义。

▲ Abstract：

Earth’s albedo is fundamental to the planetary energy budget1. The Northern Hemisphere (NH) and Southern Hemisphere (SH) contribute essentially equally to the planetary albedo—a remarkable yet puzzling phenomenon known as hemispheric albedo symmetry. Although such symmetry is rare, it is not unique. Nevertheless, other symmetry pairs have remained unexplored, despite their potential to illuminate possible causes of albedo symmetries and implications for the planetary energy budget. Using a 25-year satellite record, here we show that Earth also exhibits a unique and persistent east – west (E – W) albedo symmetry: the 27 ° E meridian divides the planet into an Eastern Hemisphere (EH) and a Western Hemisphere (WH) that reflect nearly identical amounts of sunlight. In contrast to the NH – SH symmetry, the EH – WH symmetry encapsulates a distinctive ‘triple symmetry’ in which clear-sky albedo, cloud radiative effect and open-ocean fraction all exhibit hemispheric symmetry around this meridian. This EH – WH symmetry arises from greater high-cloud reflection in the EH balancing greater low-cloud reflection in the WH. Furthermore, interannual variability in the EH – WH symmetry tracks the phase of the El Nio – Southern Oscillation (ENSO), indicating a potential connection to general circulation. This discovery of the EH – WH albedo symmetry and its emergence as a triple symmetry provides a reduced degree-of-freedom constraint for Earth system models (ESMs) and stresses the critical nature of continued Earth radiation budget observations under a rapidly changing climate.

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