Physical Review X

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PERSPECTIVE

From the Dawn of Neutrino Astronomy to a New View of the Extreme Universe

C. A. Argüelles, F. Halzen, and N. Kurahashi

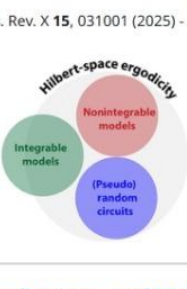
Phys. Rev. X **15**, 030501 (2025) - Published 9 July, 2025

This Perspective outlines the history of neutrino astronomy and looks ahead to the big questions that neutrino observatories may help answer.

Experimental Signatures of Hilbert-Space Ergodicity: Universal Bitstring Distributions and Applications in Noise Learning

Adam L. Shaw, Daniel K. Mark, Joonhee Choi, Ran Finkelstein, Pascal Scholl, Soonwon Choi, and Manuel Endres

Phys. Rev. X **15**, 031001 (2025) - Published 1 July, 2025

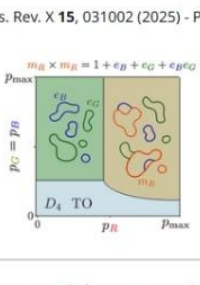


An analog quantum simulator shows that while local parts of a quantum system appear thermalized, global properties exhibit persistent, universal fluctuations—offering new insight into quantum thermalization.

Decoherence and Wave-Function Deformation of D_4 Non-Abelian Topological Order

Pablo Sala, Jason Alicea, and Ruben Verresen

Phys. Rev. X **15**, 031002 (2025) - Published 1 July, 2025

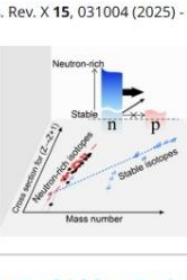


Non-Abelian topological systems show greater resistance to a certain type of noise than simpler Abelian ones, revealing new potential for building more robust quantum memories.

Charge Pickup Reaction Cross Section for Neutron-Rich p-Shell Isotopes at $900A$ MeV

J.-C. Zhang *et al.*

Phys. Rev. X **15**, 031004 (2025) - Published 2 July, 2025

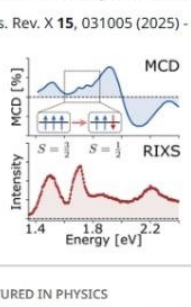


Experiments reveal that neutron-to-proton conversion in light nuclear reactions at relativistic energies rises exponentially with neutron number, challenging prior models and allowing for refined nuclear reaction and astrophysics predictions.

Spin-Forbidden Excitations in the Magneto-optical Spectra of CrI$_3$ Tuned by Covalency

Connor A. Occhialini, Luca Nessi, Luiz G. P. Martins, Ahmet Kemal Demir, Qian Song, Vicky Hasse, Chandra Shekhar, Claudia Felser, Kenji Watanabe, Takashi Taniguchi, Valentina Bisogni, Jonathan Pelliciari, and Riccardo Comin

Phys. Rev. X **15**, 031005 (2025) - Published 2 July, 2025



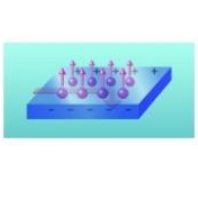
Strong optical signals in the van der Waals magnet CrI$_3$ arise from spin-forbidden chromium ion transitions enhanced by orbital hybridization with iodine atoms, offering new ways to detect and control magnetism in ultrathin materials.

FEATURED IN PHYSICS

Multipolar Anisotropy in Anomalous Hall Effect from Spin-Group Symmetry Breaking

Zheng Liu, Mengjie Wei, Wenzhi Peng, Dazhi Hou, Yang Gao, and Qian Niu

Phys. Rev. X **15**, 031006 (2025) - Published 7 July, 2025

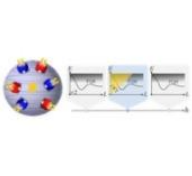


A new symmetry-breaking scenario provides a comprehensive description of magnetic behavior associated with the anomalous Hall effect.

Regularizing 3D Conformal Field Theories via Anyons on the Fuzzy Sphere

Cristian Voinea, Ruihua Fan, Nicolas Regnault, and Zlatko Papić

Phys. Rev. X **15**, 031007 (2025) - Published 7 July, 2025

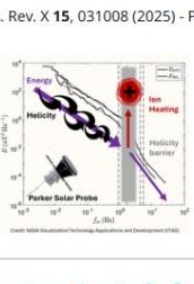


Simulations on a fuzzy sphere show that 3D Ising critical behavior persists even in fractional quantum Hall states, revealing a powerful method for studying conformal field theories amid topological order.

Evidence for the Helicity Barrier from Measurements of the Turbulence Transition Range in the Solar Wind

J. R. McIntyre, C. H. K. Chen, J. Squire, R. Meyrand, and P. A. Simon

Phys. Rev. X **15**, 031008 (2025) - Published 8 July, 2025

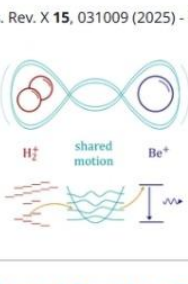


Data from NASA's Parker Solar Probe reveal that a barrier to the transfer of energy often forms in the solar wind, limiting energy reaching small scales and helping explain why solar wind protons are hotter than electrons.

Quantum Control of a Single H$_2^+$ Molecular Ion

D. Holzapfel, F. Schmid, N. Schwegler, O. Stadler, M. Stadler, A. Ferk, J. P. Home, and D. Kienzler

Phys. Rev. X **15**, 031009 (2025) - Published 8 July, 2025

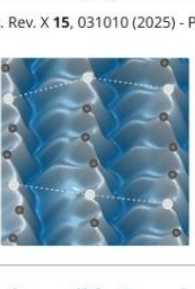


A helper ion enables full quantum control of a single H$_2^+$ ion by transferring quantum information through shared motion, allowing precise state preparation and high-resolution spectroscopy.

Coherent Structure Interactions in Spatially Extended Systems Driven by Excited Hidden Modes

Alex Round, Te-Sheng Lin, Marc Pradas, Dmitri Tseluiko, and Serafim Kalliadasis

Phys. Rev. X **15**, 031010 (2025) - Published 9 July, 2025

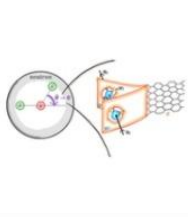


Spectral theory reveals a hidden bifurcation driving self-sustained dynamics in falling liquid films, with broad interdisciplinary implications for understanding how coherent structures interact and organize the resulting nonlinear dynamics.

Noninvertible Peccei-Quinn Symmetry and the Massless Quark Solution to the Strong CP Problem

Clay Córdova, Sungwoo Hong, and Seth Koren

Phys. Rev. X **15**, 031011 (2025) - Published 10 July, 2025



A new theory revives the ruled-out massless quark solution to the strong CP problem by linking quark color and flavor through generalized symmetries, offering a fresh path beyond the Standard Model.

Observation of Orbital-Selective Dual Modulations in an Anisotropic Antiferromagnetic Kagome Metal TbTi$_3$Bi$_4$

Renjie Zhang *et al.*

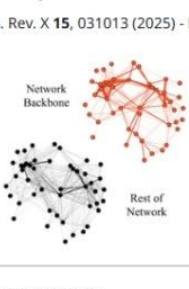
Phys. Rev. X **15**, 031012 (2025) - Published 10 July, 2025

In TbTi$_3$Bi$_4$, an orbital-specific response in the antiferromagnetic state reveals a deep connection between orbital behavior and magnetic ordering.

Fast Nonparametric Inference of Network Backbones for Weighted Graph Sparsification

Alec Kirkley

Phys. Rev. X **15**, 031013 (2025) - Published 11 July, 2025



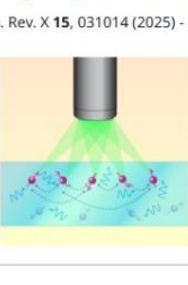
Network backboning simplifies networks by retaining only essential links. A new method for doing so relies on Bayesian inference and information theory to accomplish this automatically, without the need for fine-tuning parameters.

FEATURED IN PHYSICS

Massively Multiplexed Nanoscale Magnetometry with Diamond Quantum Sensors

Kai-Hung Cheng, Zeeshawn Kazi, Jared Rovny, Bichen Zhang, Lila S. Nassar, Jeff D. Thompson, and Nathalie P. de Leon

Phys. Rev. X **15**, 031014 (2025) - Published 14 July, 2025



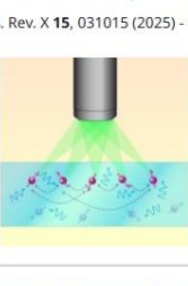
Two independent groups optimize diamond-based quantum sensing by using more than 100 such sensors in parallel.

FEATURED IN PHYSICS

Scalable Parallel Measurement of Individual Nitrogen-Vacancy Centers

Matthew Cambria, Saroj Chand, Caitlin Mary Reiter, and Shimon Kolkowitz

Phys. Rev. X **15**, 031015 (2025) - Published 14 July, 2025

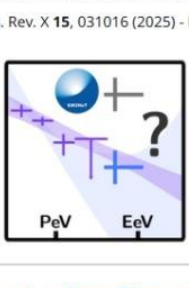


Two independent groups optimize diamond-based quantum sensing by using more than 100 such sensors in parallel.

Ultrahigh-Energy Event KM3-230213A within the Global Neutrino Landscape

O. Adriani *et al.* (KM3NeT Collaboration)

Phys. Rev. X **15**, 031016 (2025) - Published 15 July, 2025

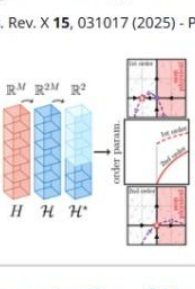


The unexpectedly high-energy neutrino detected by KM3NeT remains statistically consistent with a fluctuation. Current data cannot confirm if this detection was a hint at a new, ultrahigh-energy component in the cosmic neutrino spectrum.

Effective One-Dimensional Reduction of Multicompartment Complex Systems Dynamics

Giorgio Vittorio Visco, Johannes Nauta, Tomas Scagliarini, Oriol Artime, and Manlio De Domenico

Phys. Rev. X **15**, 031017 (2025) - Published 15 July, 2025

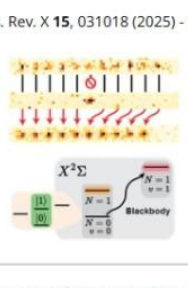


A physics-based path-integral method simplifies complex compartmental models, enabling better analysis of phase transitions in systems such as epidemics, ecosystems, and infrastructure networks.

Demonstration of Measurement-Enhanced State Preparation and Erasure Conversion in a Molecular Tweezer Array

Connor M. Holland, Yukai Lu, Samuel J. Li, Callum L. Welsh, and Lawrence W. Cheuk

Phys. Rev. X **15**, 031018 (2025) - Published 16 July, 2025

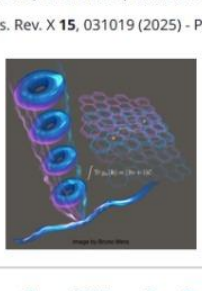


Programmable arrays of trapped molecules offer a powerful platform for quantum science. New error-mitigation strategies detect and mitigate state preparation and leakage errors by encoding faults in bright, easily detectable molecular states.

Theory of Generalized Landau Levels and Its Implications for Non-Abelian States

Zhao Liu, Bruno Mera, Manato Fujimoto, Tomoki Ozawa, and Jie Wang

Phys. Rev. X **15**, 031019 (2025) - Published 16 July, 2025

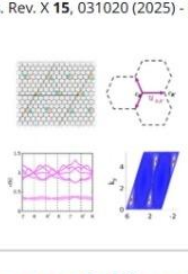


A new mathematical framework shows how differences in the internal geometry of energy bands—despite shared topology—can strongly affect the stability of certain exotic quantum states.

Fractional Wannier Orbitals and Tight-Binding Gauge Fields in Kitaev Honeycomb Superlattices with Flat Majorana Bands

K. B. Yogendra, G. Baskaran, and Tanmoy Das

Phys. Rev. X **15**, 031020 (2025) - Published 17 July, 2025

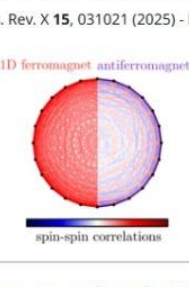


A superexchange framework for Majorana orbitals in lattice gauge theory predicts flat bands and fractional Chern states at the topological critical point, boosting future quantum technologies.

Tomonaga-Luttinger Liquid Behavior in a Rydberg-Encoded Spin Chain

Gabriel Emperauger, Mu Qiao, Cheng Chen, Filippo Caleca, Saverio Bocini, Marcus Bintz, Guillaume Bornet, Romain Martin, Bastien Gély, Lukas Klein, Daniel Barredo, Shubhayu Chatterjee, Norman Y. Yao, Fabio Mezzacapo, Thierry Lahaye, Tommaso Roscilde, and Antoine Browaeys

Phys. Rev. X **15**, 031021 (2025) - Published 17 July, 2025

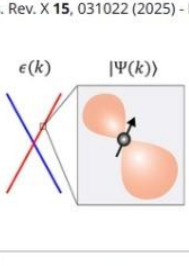


A spin chain of individually controlled atoms with long-range interactions shows how quantum correlations in a 1D system fall of with distance.

Reconstructing the Wave Function of Magnetic Topological Insulators MnBi$_2$Te$_4$ and MnBi$_4$Te$_7$ Using Spin-Resolved Photoemission

Xue Han, Jason Qu, Hengxin Tan, Zicheng Tao, Noah M. Meyer, Patrick S. Kirchmann, Yanfeng Guo, Binghai Yan, Zhi-Xun Shen, and Jonathan A. Sobota

Phys. Rev. X **15**, 031022 (2025) - Published 18 July, 2025

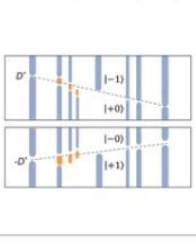


A new way to reconstruct electron wave functions reveals how electron spin and orbital angular momenta combine to influence the exotic low-temperature behavior of magnetic topological insulators.

Hetero-Orbital Two-Component Fractional Quantum Hall States in Bilayer Graphene

Ke Huang, Ajit C. Balram, Hailong Fu, Chengqi Guo, Kenji Watanabe, Takashi Taniguchi, Jainendra K. Jain, and Jun Zhu

Phys. Rev. X **15**, 031023 (2025) - Published 22 July, 2025

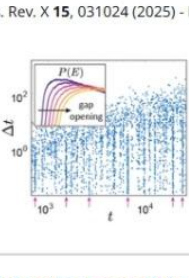


A new kind of two-component fractional quantum Hall effect state, where electrons occupy distinct orbital and valley pseudospins, suggests a novel route to engineer complex quantum phases using internal electronic degrees of freedom.

Thermal Avalanches Drive Logarithmic Creep in Disordered Media

Daniel J. Korchinski, Dor Shohat, Yoav Lahini, and Matthieu Wyart

Phys. Rev. X **15**, 031024 (2025) - Published 23 July, 2025

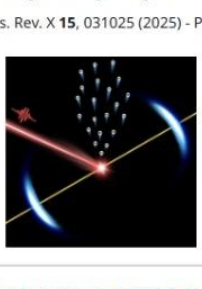


Creep in disordered materials arises from progressively harder local rearrangements, which trigger each other in slow sequences termed thermal avalanches.

Efficiently Laser Driven Terahertz Surface Plasmon Polaritons on Long Metal Wire

Shuo-ting Shao, Xiang-bing Wang, Rong Huang, Guang-yue Hu, Min Chen, Hui-bo Tang, Long-yu Kuang, Yu-xi Liu, Yu-qiu Gu, Yong-kun Ding, Hong-bin Zhuo, and Ming-yang Yu

Phys. Rev. X **15**, 031025 (2025) - Published 24 July, 2025

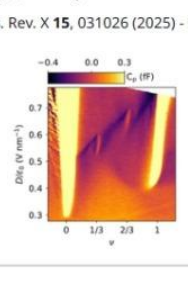


Focusing a femtosecond laser on a metal wire generates intense terahertz surface waves via subrelativistic electron emission, achieving 2.4% efficiency—enabling compact, high-power terahertz sources for imaging and communications.

Displacement Field-Controlled Fractional Chern Insulators and Charge Density Waves in a Graphene/hBN Moiré Superlattice

Samuel H. Aronson, Tonghang Han, Zhengguang Lu, Yuxuan Yao, Jackson P. Butler, Kenji Watanabe, Takashi Taniguchi, Long Ju, and Raymond C. Ashoori

Phys. Rev. X **15**, 031026 (2025) - Published 24 July, 2025



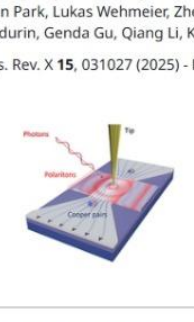
Fine-tuning electric and magnetic fields applied to a graphene/hBN moiré superlattice produces new insulating states by pushing electrons toward the moiré interface, revealing a new way that electronic interactions shape quantum phases.

FEATURED IN PHYSICS

Bolometric Superconducting Optical Nanoscopy (BOSON)

Ran Jing, Boyi Zhou, Dingchen Kang, Wenjun Zheng, Zijian Zhou, Heng Wang, Xinzhong Chen, Juntao Yao, Bing Cheng, Ji-Hoon Park, Lukas Wehmeier, Zhenbing Dai, Shoujing Chen, Christopher D. Prainito, G. L. Carr, Ilya Charaev, Denis Bandurin, Genda Gu, Qiang Li, Karl K. Berggren, D. N. Basov, Xu Du, and Mengkun Liu

Phys. Rev. X **15**, 031027 (2025) - Published 25 July, 2025

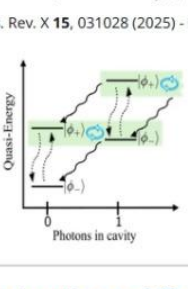


BOSON—an ultralow-power optical nanoscopy technique using superconducting sensors—enables high-resolution imaging of superconductor transition edges as well as weak polaritonic signals, opening new frontiers in quantum sensing.

Autonomous Stabilization of Floquet States Using Static Dissipation

Martin Ritter, David M. Long, Qianao Yue, Anushya Chandran, and Alicja J. Kollár

Phys. Rev. X **15**, 031028 (2025) - Published 25 July, 2025

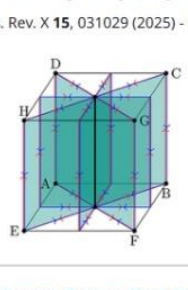


Floquet engineering can boost quantum device capabilities, and, surprisingly, adding controlled loss can reduce unwanted heating and errors, making quantum systems more stable and effective.

Construction and Classification of Crystalline Topological Superconductor and Insulators in Three-Dimensional Interacting Fermion Systems

Jian-Hao Zhang, Shang-Qiang Ning, Yang Qi, and Zheng-Cheng Gu

Phys. Rev. X **15**, 031029 (2025) - Published 28 July, 2025

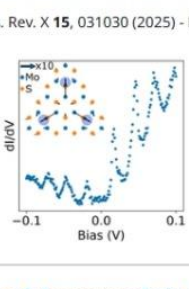


A new framework classifies 3D crystalline topological phases in interacting fermion systems, revealing experimentally relevant surface states and nuanced connections between spinless and spin-1/2 fermions.

Inelastic Tunneling into Multipolaronic Bound States in Single-Layer MoS$_2$

Camiel van Efferen, Laura Pätzold, Tfyeche Y. Tounsi, Arne Schobert, Michael Winter, Yann in 't Veld, Mark Georger, Affan Safeer, Christian Krämer, Jeison Fischer, Jan Berges, Thomas Michely, Roberto Mozara, Tim Wehling, and Wouter Jolie

Phys. Rev. X **15**, 031030 (2025) - Published 29 July, 2025



Experiments and theory provide direct evidence of multipolaronic bound states in metallic monolayer MoS$_2$, shedding light on how electrons behave in two-dimensional semiconductors.

Speed-Accuracy Relations for Diffusion Models: Wisdom from Nonequilibrium Thermodynamics and Optimal Transport

Kotaro Ikeda, Tomoya Uda, Daisuke Okanohara, and Sosuke Ito

Phys. Rev. X **15**, 031031 (2025) - Published 30 July, 2025

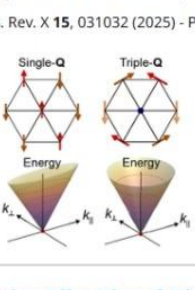
Dissipation
Error
Data generation

An analysis that draws on nonequilibrium thermodynamics shows that thermodynamic dissipation limits data quality in diffusion models and that optimal transport dynamics yields more accurate generation than typical empirical methods.

Spin Dynamics of Triple-Q Magnetic Orderings in a Triangular Lattice: Implications for Multi-Q Orderings in General Two-Dimensional Lattices

Pyeongjae Park, Woonghee Cho, Chaebin Kim, Yeochan An, Kazuki Iida, Ryoichi Kajimoto, Sakib Matin, Shang-Shun Zhang, Cristian D. Batista, and Je-Geun Park

Phys. Rev. X **15**, 031032 (2025) - Published 30 July, 2025

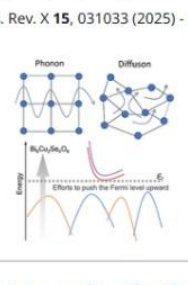


Unlike conventional magnetic orders, topological spin textures in two-dimensional magnets show isotropic spin-wave speeds, offering a clear, general feature to identify topological order, aiding spintronics and magnetic materials discovery.

Lattice Vibrational Hierarchy and Mean-Free-Path Filtering in Bi$_6$Cu$_2$Se$_4$O$_6$ Superlattice Thermoelectrics

Shulin Bai, Haonan Shi, Yi Wen, Yixuan Hu, Junqing Zheng, Yongxin Qin, Lizhong Su, Shibo Liu, Dongrui Liu, Tian Gao, Tao Hong, Xiang Gao, Fangyuan Zhu, Bingchao Qin, and Li-Dong Zhao

Phys. Rev. X **15**, 031033 (2025) - Published 31 July, 2025

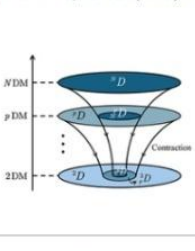


Bi$_6$Cu$_2$Se$_4$O$_6$ emerges as a promising air-stable n-type thermoelectric oxide, with unique lattice dynamics—like bismuth rattling and copper vibrations—offering new ways to enhance heat-to-electricity conversion.

Bootstrapping the Quantum Hall Problem

Qiang Gao, Ryan A. Lanzetta, Patrick Ledwith, Jie Wang, and Eslam Khalaf

Phys. Rev. X **15**, 031034 (2025) - Published 31 July, 2025

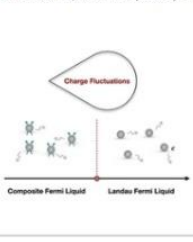


Relying on bootstrap methods from high-energy physics provides a way to study strongly interacting electrons in quantum Hall systems without constructing complex wave functions, revealing new insights into both gapped and gapless phases.

Bipartite Fluctuations of Critical Fermi Surfaces

Xiao-Chuan Wu

Phys. Rev. X **15**, 031035 (2025) - Published 6 August, 2025

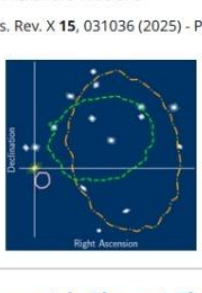


Shape-dependent charge fluctuations in metals reveal a universal "corner term" that serves as a fingerprint for a class of unconventional quantum phase transitions driven by strong electron interactions.

Systematic Biases in Estimating the Properties of Black Holes Due to Inaccurate Gravitational-Wave Models

Arnab Dhani, Sebastian H. Völkel, Alessandra Buonanno, Hector Estelles, Jonathan Gair, Harald P. Pfeiffer, Lorenzo Pompili, and Alexandre Toubiana

Phys. Rev. X **15**, 031036 (2025) - Published 8 August, 2025

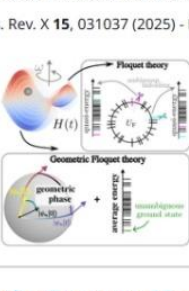


Even the most advanced models used to interpret gravitational-wave signals can introduce systematic errors in estimating black-hole properties—especially for rapidly spinning black holes or unequal-mass binaries.

Geometric Floquet Theory

Paul M. Schindler and Marin Bukov

Phys. Rev. X **15**, 031037 (2025) - Published 8 August, 2025

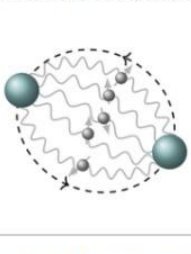


A new geometric reformulation of Floquet theory introduces a way to uniquely define ground energies for Floquet states, enabling clearer classification of nonequilibrium phases and improved simulation of driven quantum systems.

On the Quantum Mechanics of Entropic Forces

Daniel Carney, Manthos Karydas, Thilo Scharnhorst, Roshni Singh, and Jacob M. Taylor

Phys. Rev. X **15**, 031038 (2025) - Published 11 August, 2025

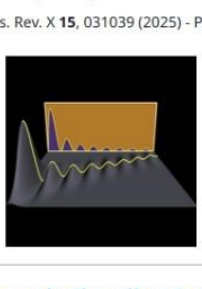


A detailed quantum model of how gravity might emerge from microscopic spacetime constituents, like spacetime "molecules," offers testable predictions that distinguish it from particle-based gravity and paves the way for experimental probes.

Algebraic Non-Hermitian Skin Effect and Generalized Fermi Surface Formula in Arbitrary Dimensions

Kai Zhang, Chang Shu, and Kai Sun

Phys. Rev. X **15**, 031039 (2025) - Published 11 August, 2025

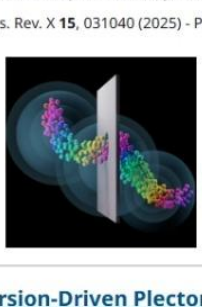


A newly identified algebraic non-Hermitian skin effect reveals that in higher-dimensional quantum systems, boundary-localized modes can decay by a power law, unlocking new ways to control quantum transport and entanglement.

Acoustic Signaling Enables Collective Perception and Control in Active Matter Systems

Alexander Ziepke, Ivan Maryshev, Igor S. Aranson, and Erwin Frey

Phys. Rev. X **15**, 031040 (2025) - Published 12 August, 2025

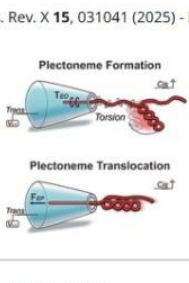


Self-propelled particles that emit and respond to sound can self-organize into dynamic, resilient structures—like snakes and rings—that sense, decide, and recover, offering a new path to smart, adaptable microrobotic swarms.

Torsion-Driven Plectoneme Formation During Nanopore Translocation of DNA Polymers

Fei Zheng, Antonio Suma, Christopher Maffeo, Kaikai Chen, Mohammed Alawami, Jingjie Sha, Aleksei Aksimentiev, Cristian Micheletti, and Ulrich F. Keyser

Phys. Rev. X **15**, 031041 (2025) - Published 12 August, 2025



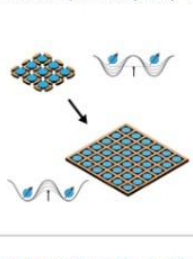
Plectonemes—twisted DNA structures—form frequently during nanopore experiments and produce distinct signals, challenging the long-held belief that such signals result from DNA knots.

FEATURED IN PHYSICS

Operating Semiconductor Qubits without Individual Barrier Gates

Alexander S. Ivlev, Damien R. Crielaard, Marcel Meyer, William I. L. Lawrie, Nico W. Hendrickx, Amir Sammak, Yuta Matsumoto, Lieven M. K. Vandersypen, Giordano Scappucci, Corentin Déprez, and Menno Veldhorst

Phys. Rev. X **15**, 031042 (2025) - Published 14 August, 2025

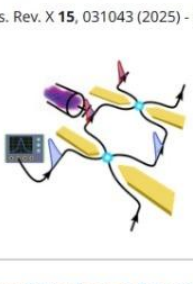


A new method for controlling spin qubits in quantum dots reduces wiring complexity by tuning qubit energy levels instead of individual barriers, enabling scalable architectures without sacrificing performance.

Quantum Sensing of Time-Dependent Electromagnetic Fields with Single-Electron Excitations

H. Souquet-Basiège, B. Roussel, G. Rebora, G. Ménard, I. Safi, G. Fève, and P. Degiovanni

Phys. Rev. X **15**, 031043 (2025) - Published 14 August, 2025

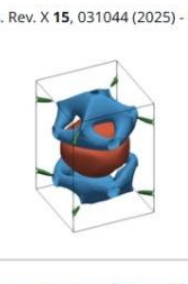


A proposed on-chip "electron radar" uses single-electron interferometry to probe ultrafast, low-energy quantum electromagnetic fields with picosecond resolution, enabling direct detection of field strength and quantum fluctuations.

Fermi Surface of RuO$_2$ Measured by Quantum Oscillations

Zheyu Wu, Mengmeng Long, Hanyi Chen, Shubhankar Paul, Hisakazu Matsuki, Oleksandr Zheliuk, Uli Zeitler, Gang Li, Rui Zhou, Zengwei Zhu, Dave Graf, Theodore I. Weinberger, F. Malte Grosche, Yoshiteru Maeno, and Alexander G. Eaton

Phys. Rev. X **15**, 031044 (2025) - Published 18 August, 2025

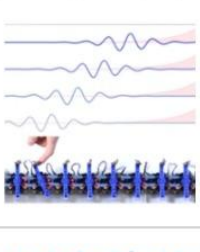


Quantum oscillation measurements reveal that RuO$_2$ lacks the bulk magnetic properties expected of an altermagnet, suggesting previous signals arose from surface effects and underscoring the need for bulk-sensitive probes in spintronics research.

Nonreciprocal Breathing Solitons

Jonas Veenstra, Oleksandr Gamayun, Martin Brandenbourger, Freek van Gorp, Hans Terwisscha-Dekker, Jean-Sébastien Caux, and Corentin Coulais

Phys. Rev. X **15**, 031045 (2025) - Published 18 August, 2025

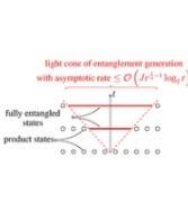


Breathing solitons can persist in energy-losing systems by leveraging nonreciprocal dynamics, enabling stable wave motion for efficient signaling, energy transport, and adaptive materials.

Dynamical α-Rényi Entropies of Local Hamiltonians Grow at Most Linearly in Time

Daniele Toniolo and Sougato Bose

Phys. Rev. X **15**, 031046 (2025) - Published 19 August, 2025

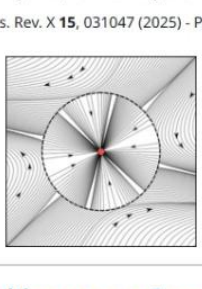


Linking the Lieb-Robinson bound to entanglement growth shows that faster information spread yields greater entanglement, providing a way to estimate computational complexity via measurable quantities.

Rotations, Negative Eigenvalues, and Newton Method in Tensor Network Renormalization Group

Nikolay Ebel, Tom Kennedy, and Slava Rychkov

Phys. Rev. X **15**, 031047 (2025) - Published 19 August, 2025

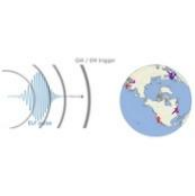


Incorporating lattice rotation into the renormalization group (RG) procedure offers a high-precision method for directly computing RG fixed-point tensors, paving the way for more rigorous and automated analysis of critical behavior in statistical physics.

Multimessenger Search for Exotic Field Emission with a Global Magnetometer Network

Sami S. Khamis *et al.*

Phys. Rev. X **15**, 031048 (2025) - Published 20 August, 2025

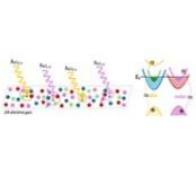


Black hole mergers may emit bursts of unknown particles. A search of data from a global magnetometer network during a gravitational-wave event, while not turning up such signals, sets the first lab-based limits on exotic emissions tied to dark matter.

Energy Shifts and Broadening of Excitonic Resonances in Electrostatically Doped Semiconductors

Hanan Dery, Cedric Robert, Scott A. Crooker, Xavier Marie, and Dinh Van Tuan

Phys. Rev. X **15**, 031049 (2025) - Published 21 August, 2025

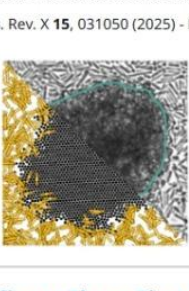


Two fundamental concepts—distinguishability and optimality—are primary factors that govern the behavior of optical resonances in charge-tunable semiconductors.

Synthetic Quorum Sensing and Absorbing Phase Transitions in Colloidal Active Matter

Thibault Lefranc, Alberto Dinelli, Carla Fernández-Rico, Roel P. A. Dullens, Julien Tailleur, and Denis Bartolo

Phys. Rev. X **15**, 031050 (2025) - Published 22 August, 2025

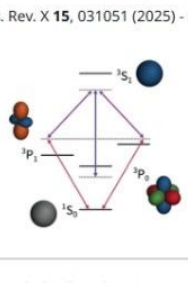


Microscopic self-propelled rods with built-in quorum sensing adapt their motion to local crowding—rolling in sparse areas and halting in dense ones—leading to dynamic pattern formation and collective freezing behavior.

Collinear Three-Photon Excitation of a Strongly Forbidden Optical Clock Transition

Samuel P. Carman, Jan Rudolph, Benjamin E. Garber, Michael J. Van de Graaff, Hunter Swan, Yijun Jiang (姜一君), Megan Nantel, Mahiro Abe, Rachel L. Barclay, and Jason M. Hogan

Phys. Rev. X **15**, 031051 (2025) - Published 22 August, 2025

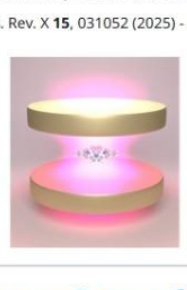


A new three-photon method enables precise clock transitions in bosonic atoms—previously limited to fermions—unlocking their use in advanced quantum sensors, interferometers, and timekeeping technologies.

Relativistic Linear Response in Quantum-Electrodynamical Density Functional Theory

Lukas Konecny, Valeriia P. Kosheleva, Heiko Appel, Michael Ruggenthaler, and Angel Rubio

Phys. Rev. X **15**, 031052 (2025) - Published 25 August, 2025

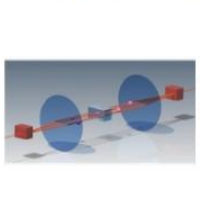


A new theoretical framework combines strong light-matter coupling with relativistic quantum effects, revealing how optical cavities can control spin-orbit interactions and modify formally forbidden transitions in heavy atoms.

Quantum Storage of Qubits in an Array of Independently Controllable Solid-State Quantum Memories

Markus Teller, Susana Plascencia, Samuele Grandi, and Hugues de Riedmatten

Phys. Rev. X **15**, 031053 (2025) - Published 25 August, 2025

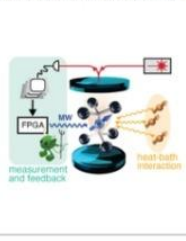


An array of ten independently controlled quantum memory cells stores photonic qubits in a rare-earth crystal, advancing the development of scalable, RAM-like storage for photonic quantum computing.

Experimentally Probing Entropy Reduction via Iterative Quantum Information Transfer

Toshihiro Yada, Pieter-Jan Stas, Aziza Suleymanzade, Erik N. Knall, Nobuyuki Yoshioka, Takahiro Sagawa, and Mikhail D. Lukin

Phys. Rev. X **15**, 031054 (2025) - Published 26 August, 2025

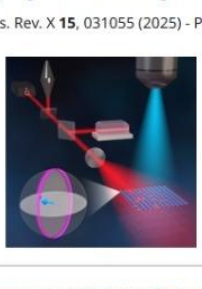


Tracking real-time feedback on a spin qubit reveals how quantum information flow sets thermodynamic limits and shows that feedback with memory enables enhanced control performance compared to memoryless methods.

High-Power Clock Laser Spectrally Tailored for High-Fidelity Quantum State Engineering

Lingfeng Yan, Stefan Lannig, William R. Milner, Max N. Frankel, Ben Lewis, Dahyeon Lee, Kyungtae Kim, and Jun Ye

Phys. Rev. X **15**, 031055 (2025) - Published 26 August, 2025

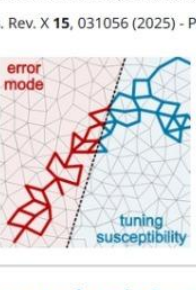


A custom-designed optical clock laser achieves notably high, single-qubit optical-gate fidelity across 3000 atoms, advancing scalable, high-precision control for quantum computing, sensing, and next-generation atomic clocks.

Microscopic Imprints of Learned Solutions in Tunable Networks

Marcelo Guzman, Felipe Martins, Menachem Stern, and Andrea J. Liu

Phys. Rev. X **15**, 031056 (2025) - Published 27 August, 2025

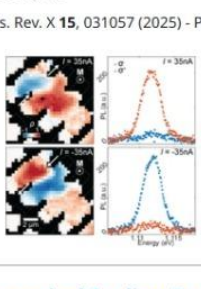


Physical constraints on networks, such as electrical resistor networks that learn on their own, offer interpretable insights into how learning tasks are performed and suggest a universal framework that extends to mechanical and biological systems.

Magnetoelectric Control of Helical Light Emission in a Moiré Chern Magnet

Eric Anderson, Heonjoon Park, Kaijie Yang, Jiaqi Cai, Takashi Taniguchi, Kenji Watanabe, Liang Fu, Ting Cao, Di Xiao, and Xiaodong Xu

Phys. Rev. X **15**, 031057 (2025) - Published 27 August, 2025

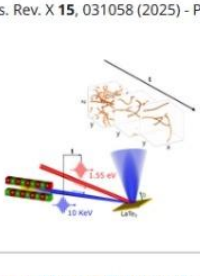


Efficient, all-electrical control of magnetism and light polarization in twisted bilayer MoTe$_2$ demonstrates a way to link magnetic memory and optical communication in one device and offers a new tuning knob for manipulating zero-field anyons.

Dynamical Scaling Reveals Topological Defects and Anomalous Evolution of a Photoinduced Phase Transition

Gal Orenstein, Ryan A. Duncan, Gilberto A. de la Peña Muñoz, Yijing Huang, Viktor Krapivin, Quynh Le Nguyen, Samuel Teitelbaum, Anisha G. Singh, Roman Mankowsky, Henrik Lemke, Mathias Sander, Yunpei Deng, Christopher Arrell, Ian R. Fisher, David A. Reis, and Mariano Trigo

Phys. Rev. X **15**, 031058 (2025) - Published 28 August, 2025

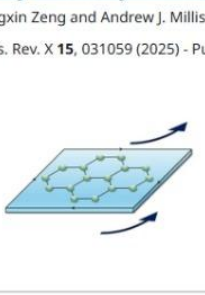


Ultrafast x-ray scattering reveals that light-excited charge density waves in LaTe$_3$ relax slowly due to vortexlike topological defects, showing glasslike behavior and subdiffusive dynamics at the nanoscale.

Berry Phase Dynamics of Sliding Electron Crystals

Yongxin Zeng and Andrew J. Millis

Phys. Rev. X **15**, 031059 (2025) - Published 28 August, 2025



Sliding electron crystals acquire a transverse velocity under an electric field because of nontrivial quantum geometry, breaking Galilean invariance and altering Hall conductance in materials like rhombohedral graphene.

Efficient Preparation of Solvable Anyons with Adaptive Quantum Circuits

Yuanjie Ren, Nathanan Tantivasadakarn, and Dominic J. Williamson

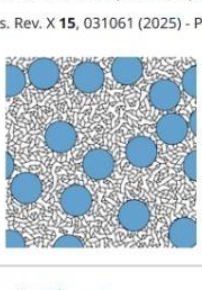
Phys. Rev. X **15**, 031060 (2025) - Published 29 August, 2025

Adaptive quantum circuits can efficiently generate and control solvable anyons—including complex non-Abelian types—offering a comprehensive, constant-time method for preparing topological phases on quantum devices.

Criticality Enhances the Reinforcement of Disordered Networks by Rigid Inclusions

Jordan L. Shivers, Jingchen Feng, and Fred C. MacKintosh

Phys. Rev. X **15**, 031061 (2025) - Published 2 September, 2025

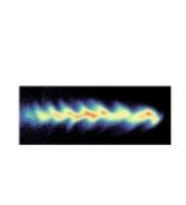


Near a mechanical critical point, adding even a small amount of rigid material to soft fiber networks causes unexpectedly large stiffness increases, revealing new ways to design tunable, responsive materials.

Single-Shot Reconstruction of Electron Beam Longitudinal Phase Space in a Laser Wakefield Accelerator

Y. Ma *et al.*

Phys. Rev. X **15**, 031062 (2025) - Published 2 September, 2025



A technique for fully mapping the ultrashort electron beams for laser wakefield acceleration eases the path to creating compact next-generation x-ray free-electron lasers.

FEATURED IN PHYSICS

Quantum Effects in Gravity Beyond the Newton Potential from a Delocalized Quantum Source

Lin-Qing Chen and Flaminia Giacomini

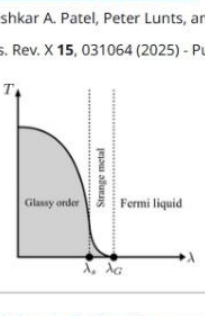
Phys. Rev. X **15**, 031063 (2025) - Published 4 September, 2025

New predictions from linearized quantum gravity show that delocalized sources and gravitational-field commutators could offer stronger evidence for future experiments that gravity is inherently quantum.

Strange Metals and Planckian Transport in a Gapless Phase from Spatially Random Interactions

Aavishkar A. Patel, Peter Lunts, and Michael S. Albergo

Phys. Rev. X **15**, 031064 (2025) - Published 8 September, 2025

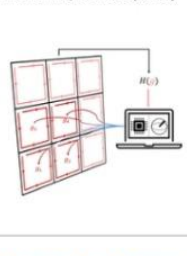


A simple, realistic model shows that electrons scattering off localized magnetic modes created by heterogeneous interactions explains strange metals' linear resistance and universal scattering rate in high-temperature superconductors.

Efficient Finite-Resource Formulation of Non-Abelian Lattice Gauge Theories beyond One Dimension

Pierpaolo Fontana, Marc Miranda-Riaza, and Alessio Celi

Phys. Rev. X **15**, 031065 (2025) - Published 9 September, 2025

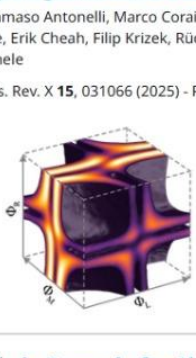


A new quantum-compatible method simplifies non-Abelian gauge theory simulations by compressing gauge field data, enabling accurate predictions across interaction strengths with limited quantum resources.

Exploring the Energy Spectrum of a Four-Terminal Josephson Junction: Toward Topological Andreev Band Structures

Tommaso Antonelli, Marco Coraiola, David Christian Ohnmacht, Aleksandr E. Svetogorov, Deividas Sabonis, Sofieke C. ten Kate, Erik Cheah, Filip Krizek, Rüdiger Schott, Juan Carlos Cuevas, Wolfgang Belzig, Werner Wegscheider, and Fabrizio Nichele

Phys. Rev. X **15**, 031066 (2025) - Published 9 September, 2025



A four-terminal superconducting device that simulates a 3D band structure offers the first step toward realizing Weyl states that could provide topological protection to future quantum devices.

Středa Formula for Floquet Systems: Topological Invariants and Quantized Anomalies from Cesàro Summation

Lucila Peralta Gavensky, Gonzalo Usaj, and Nathan Goldman

Phys. Rev. X **15**, 031067 (2025) - Published 10 September, 2025

A nonequilibrium extension of the Středa formula provides a physical framework for the topological classification of Floquet systems, revealing universal quantized magnetic responses in driven settings.

Optimal Time Estimation and the Clock Uncertainty Relation for Stochastic Processes

Kacper Prech, Gabriel T. Landi, Florian Meier, Nuriya Nurgalieva, Patrick P. Potts, Ralph Silva, and Mark T. Mitchison

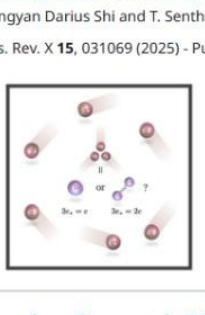
Phys. Rev. X **15**, 031068 (2025) - Published 11 September, 2025

A sequence of random events can act as a clock, and its accuracy is fundamentally limited by how often those events occur, as shown by a new bound linking timekeeping precision to the statistics of waiting times.

Doping a Fractional Quantum Anomalous Hall Insulator

Zhengyan Darius Shi and T. Senthil

Phys. Rev. X **15**, 031069 (2025) - Published 11 September, 2025

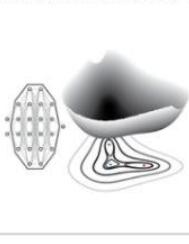


A universal field-theoretic framework to describe the doping of fractional quantum anomalous Hall insulators predicts that a nonzero density of mobile anyons form exotic metals and superconductors.

Learning Geometric Models for Developmental Dynamics

Addison Howe and Madhav Mani

Phys. Rev. X **15**, 031070 (2025) - Published 15 September, 2025

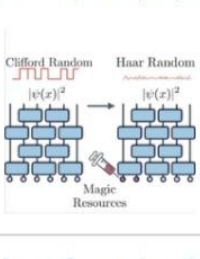


A neural network model that learns a "developmental landscape" linked to underlying genes provides a framework for understanding tissue formation and differentiation.

Anticoncentration in Clifford Circuits and Beyond: From Random Tensor Networks to Pseudomagic States

Beatrice Magni, Alexios Christopoulos, Andrea De Luca, and Xhek Turkeshi

Phys. Rev. X **15**, 031071 (2025) - Published 15 September, 2025

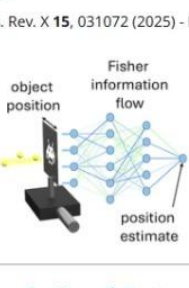


An analysis of how evenly quantum states spread out in Clifford circuits and tensor networks provides new insights for quantum sampling, benchmarking, and computational quantum advantage.

Fisher Information Flow in Artificial Neural Networks

Maximilian Weimar, Lukas M. Rachbauer, Ilya Starshynov, Daniele Faccio, Linara Adilova, Dorian Bouchet, and Stefan Rotter

Phys. Rev. X **15**, 031072 (2025) - Published 16 September, 2025

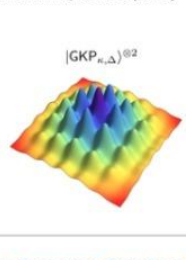


A new algorithm tracks Fisher information through a neural network, revealing how information flows and transforms and offering guidance for designing more efficient networks.

Complexity of Gottesman-Kitaev-Preskill States

Lukas Brenner, Libor Caha, Xavier Coiteux-Roy, and Robert Koenig

Phys. Rev. X **15**, 031073 (2025) - Published 19 September, 2025

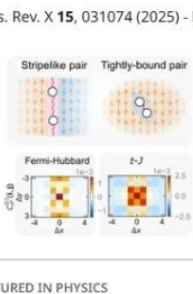


A proposed protocol efficiently prepares high-quality Gottesman-Kitaev-Preskill (GKP) quantum states with rigorous accuracy guarantees. Since GKP states are central to quantum error correction, this paves the way for more robust quantum computing.

Two-Dopant Origin of Competing Stripe and Pair Formation in Hubbard and t–J Models

Tizian Blatz, Ulrich Schollwöck, Fabian Grusdt, and Annabelle Bohrdt

Phys. Rev. X **15**, 031074 (2025) - Published 24 September, 2025



A single pair of charge carriers can reveal the competition between superconducting and insulating phases in the microscopic models describing high-temperature superconductors.

FEATURED IN PHYSICS

Teleportation and Entanglement Swapping of Continuous Quantum Variables of Microwave Radiation

Baleegh Abdo, William Shanks, Oblesh Jinka, J. R. Rozen, and Jason Orcutt

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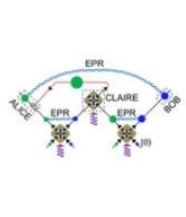

A superconducting Josephson mixer generates continuous-variable entanglement between microwave modes, enabling teleportation and entanglement swapping with fidelities beyond classical limits—key steps toward scalable quantum networks.

Prototypes of Nonrelativistic Spin Splitting and Polarization in Symmetry Broken Antiferromagnets

Xiuwen Zhang, Jia-Xin Xiong, Lin-Ding Yuan, and Alex Zunger

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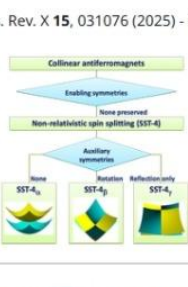
Collinear antiferromagnets
Enabling symmetries
Non-relativistic spin splitting (SST-4)
Auxiliary symmetries

Breaking key symmetries in antiferromagnets enables nonrelativistic spin splitting without spin-orbit coupling, with auxiliary symmetries guiding a classification that predicts distinct spin polarization patterns for spintronic materials design.

Thermal Transport in a 2D Amorphous Material

Yuxi Wang, Nianjie Liang, Xingxing Zhang, Wujuan Yan, Haiyu He, Alfredo Fiorentino, Xinwei Tao, Ang Li, Fuwei Yang, Buxuan Li, Te-Huan Liu, Jia Zhu, Wu Zhou, Wei Wang, Stefano Baroni, Lin Zhou, and Bai Song

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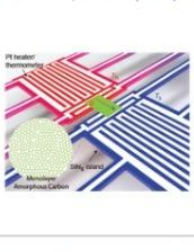

Monolayer amorphous carbon shows unexpectedly high in-plane thermal conductivity compared to its 3D form, revealing how reduced dimensionality can reshape heat transport in disordered materials.

Exciton Formation in Two-Dimensional Semiconductors

K. Mourzidis, V. Jindal, M. Glazov, A. Balocchi, C. Robert, D. Lagarde, P. Renucci, L. Lombez, T. Taniguchi, K. Watanabe, T. Amand, S. Francoeur, and X. Marie

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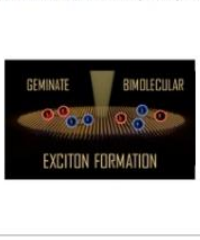

Excitons in two-dimensional transition-metal dichalcogenide monolayers form through both geminate and bimolecular pathways, resolving a key debate and enabling new control over exciton properties for quantum applications.

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