Physical Review X

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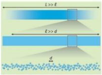
PERSPECTIVE

Generalized Hydrodynamics: A Perspective

Benjamin Doyon, Sarang Gopalakrishnan, Frederik Møller, Jörg Schmiedmayer, and Romain Vasseur

Phys. Rev. X **15**, 010501 (2025) - Published 29 January, 2025



Entanglement Properties of Gauge Theories from Higher-Form Symmetries

Wen-Tao Xu, Tibor Rakovszky, Michael Knap, and Frank Pollmann

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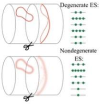
Phys. Rev. X **15**, 011001 (2025) - Published 2 January, 2025



An analysis of entanglement properties in a gauge theory with higher-form symmetries makes an essential step toward the complete understanding of quantum phases of matter.

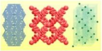
FEATURED IN PHYSICS

Scaling Law for Intrinsic Fracture Energy of Diverse Stretchable Networks

Chase Hartquist, Shu Wang, Qiaodong Cui, Wojciech Matusik, Bolei Deng, and Xuanhe Zhao

Phys. Rev. X **15**, 011002 (2025) - Published 8 January, 2025

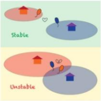
The energy required to fracture a lattice material obeys a scaling law governed by just three parameters, researchers find.



Complex Ecosystems Lose Stability When Resource Consumption Is Out of Niche

Yizhou Liu, Jiliang Hu, Hyunseok Lee, and Jeff Gore

Phys. Rev. X **15**, 011003 (2025) - Published 10 January, 2025

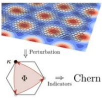


A simple theoretical framework predicts that complex communities lose stability when species consume resources out of their niche.

Efficient Prediction of Superlattice and Anomalous Miniband Topology from Quantum Geometry

Valentin Crépel and Jennifer Cano

Phys. Rev. X **15**, 011004 (2025) - Published 13 January, 2025

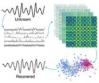


Predicting which superlattice materials are best for observing specific topological states is often computationally prohibitive. A new method for doing so bypasses that hurdle.

Recurrences Reveal Shared Causal Drivers of Complex Time Series

William Gilpin

Phys. Rev. X **15**, 011005 (2025) - Published 13 January, 2025

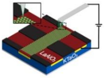


Many complex systems are driven by unobserved causal forces. A new physics-based algorithm can reconstruct such hidden causes from downstream signals.

Superconducting Quantum Oscillations and Anomalous Negative Magnetoresistance in a Honeycomb Nanopatterned Oxide Interface Superconductor

Yishuai Wang, Siyuan Hong, Wenze Pan, Yi Zhou, and Yanwu Xie

Phys. Rev. X **15**, 011006 (2025) - Published 14 January, 2025



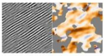
Magnetoresistance measurements of an oxide-interface superconductor points to the potential of such materials as a platform for exploring exotic quantum states.

FEATURED IN PHYSICS

Atomic-Scale Tracking of Topological Defect Motion and Incommensurate Charge Order Melting

Noah Schnitzer, Berit H. Goodge, Gregory Powers, Jaewook Kim, Sang-Wook Cheong, Ismail El Baggari, and Lena F. Kourkoutis

Phys. Rev. X **15**, 011007 (2025) - Published 15 January, 2025

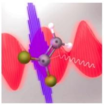


A cryogenic microscope reveals the atomic-scale processes that disrupt the charge-ordered state in a material as the temperature rises.

Probing Electronic Coherence between Core-Level Vacancies at Different Atomic Sites

Jun Wang *et al.*

Phys. Rev. X **15**, 011008 (2025) - Published 16 January, 2025

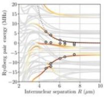


An attosecond x-ray method reveals a type of electronic evolution in molecules driven by quantum coherence, paving the way to new insights into collective electron motion during the first moments of light-matter interaction.

Spectroscopy and Modeling of $^{171}\mathrm{Yb}$ Rydberg States for High-Fidelity Two-Qubit Gates

Michael Peper, Yiyi Li, Daniel Y. Knapp, Mila Bileska, Shuo Ma, Genyue Liu, Pai Peng, Bichen Zhang, Sebastian P. Horvath, Alex P. Burgers, and Jeff D. Thompson

Phys. Rev. X **15**, 011009 (2025) - Published 17 January, 2025

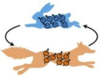


Experimentally validated modeling of the Rydberg states of Yb leads to a two-qubit quantum gate with higher fidelity than previous Yb Rydberg gates.

Nonreciprocal Synchronization of Active Quantum Spins

Tobias Nadolny, Christoph Bruder, and Matteo Brunelli

Phys. Rev. X **15**, 011010 (2025) - Published 21 January, 2025

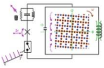


A model of nonreciprocal interactions among quantum spins reveals the emergence of persistent, collective dynamics analogous to a never-ending chase-and-escape motion among the spins.

Dissipative Protection of a GKP Qubit in a High-Impedance Superconducting Circuit Driven by a Microwave Frequency Comb

L.-A. Sellem, A. Sarlette, Z. Leghtas, M. Mirrahimi, P. Rouchon, and P. Campagne-Ibarcq

Phys. Rev. X **15**, 011011 (2025) - Published 22 January, 2025

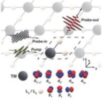


Bosonic qubits are promising platforms for quantum error correction. A new approach to detecting errors ensures precise control of the extracted information.

Time-Resolved X-Ray Spectroscopy from the Atomic Orbital Ground State Up

Daniel Jost, Eder G. Lomeli, Ta Tang, Joshua J. Kas, John J. Rehr, Wei-Sheng Lee, Hong-Chen Jiang, Brian Moritz, and Thomas P. Devereaux

Phys. Rev. X **15**, 011012 (2025) - Published 23 January, 2025



Simulations of x-ray spectroscopies demonstrate the insights that can be obtained from charge-transfer pumping and how this process affects ground- and excited-state properties.

FEATURED IN PHYSICS

Neural Density Functional Theory of Liquid-Gas Phase Coexistence

Florian Sammüller, Matthias Schmidt, and Robert Evans

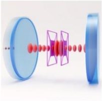
Phys. Rev. X **15**, 011013 (2025) - Published 24 January, 2025

Conventional theory has trouble predicting the conditions that will cause a liquid to boil, but a neural-network-based approach performs better.

Long-Range Optomechanical Interactions in SiN Membrane Arrays

Xiong Yao, Matthijs H. J. de Jong, Jie Li, and Simon Gröblacher

Phys. Rev. X **15**, 011014 (2025) - Published 27 January, 2025

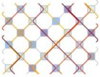


Interactions between light and a vibrating membrane are a cornerstone of many light-matter experiments. A new setup achieves a long-predicted boost to the optomechanical coupling rate with the use of two membranes.

Quantum and Classical Dynamics with Random Permutation Circuits

Bruno Bertini, Katja Klobas, Pavel Kos, and Daniel Malz

Phys. Rev. X **15**, 011015 (2025) - Published 28 January, 2025

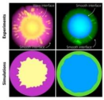


A framework for studying quantum and classical many-body dynamics on equal footing reveals that, despite their fundamental differences, they can look remarkably similar.

Interfacial Morphodynamics of Proliferating Microbial Communities

Alejandro Martínez-Calvo, Carolina Trenado-Yuste, Hyunseok Lee, Jeff Gore, Ned S. Wingreen, and Sujit S. Datta

Phys. Rev. X **15**, 011016 (2025) - Published 29 January, 2025



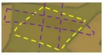
The shape of interfaces between domains of differing cell types arises from differences in cell proliferation rates and substrate friction, an insight that offers a biophysical basis for understanding such interfaces in microbial communities.

FEATURED IN PHYSICS

Positive Oscillating Magnetoresistance in a van der Waals Antiferromagnetic Semiconductor

Xiaohanwen Lin, Fan Wu, Nicolas Ubrig, Menghan Liao, Fengrui Yao, Ignacio Gutiérrez-Lezama, and Alberto F. Morpurgo

Phys. Rev. X **15**, 011017 (2025) - Published 30 January, 2025

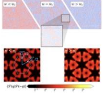


At low temperatures the resistance of a layered magnetic semiconductor shoots up and down in response to an increasing magnetic field.

Flux Fractionalization Transition in Anisotropic $S = 1$ Antiferromagnets and Dimer-Loop Models

Souvik Kundu and Kedar Damle

Phys. Rev. X **15**, 011018 (2025) - Published 31 January, 2025

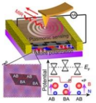


A system of spin-1 moments on a kagome lattice produces intriguing spin-liquid behavior, offering clues for progress toward realizing such spin liquids in experiments.

Plasmonic Polarization Sensing of Electrostatic Superlattice Potentials

Shuai Zhang, Jordan Fonseca, Daniel Bennett, Zhiyuan Sun, Junhe Zhang, Ran Jing, Suheng Xu, Leo He, S. L. Moore, S. E. Rossi, Dmitry Ovchinnikov, David Cobden, Pablo Jarillo-Herrero, M. M. Fogler, Philip Kim, Efthimios Kaxiras, Xiaodong Xu, and D. N. Basov

Phys. Rev. X **15**, 011019 (2025) - Published 31 January, 2025

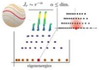


In a heterostructure of graphene and twisted boron nitride, the plasmonic response of the former can be used to probe the electric polarization of the latter, opening a new path for exploring a broad range of exotic ferroelectric or polar materials.

Theory of Robust Quantum Many-Body Scars in Long-Range Interacting Systems

Alessio Lerose, Tommaso Parolini, Rosario Fazio, Dmitry A. Abanin, and Silvia Pappalardi

Phys. Rev. X **15**, 011020 (2025) - Published 3 February, 2025



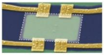
A demonstration of quantum many-body scars arising from long-range interactions implies a surprising breakdown of conventional thermal equilibrium.

FEATURED IN PHYSICS

Hybrid Josephson Rhombus: A Superconducting Element with Tailored Current-Phase Relation

L. Banszerus, C. W. Andersson, W. Marshall, T. Lindemann, M. J. Manfra, C. M. Marcus, and S. Vaitiekėnas

Phys. Rev. X **15**, 011021 (2025) - Published 4 February, 2025

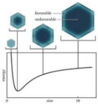


A circuit containing four superconducting devices called Josephson junctions can be finely tuned for various technological applications.

Collective Deformation Modes Promote Fibrous Self-Assembly in Deformable Particles

Hugo Le Roy, M. Mert Terzi, and Martin Lenz

Phys. Rev. X **15**, 011022 (2025) - Published 4 February, 2025

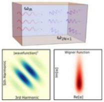


Fibrous aggregates provide an effective way for self-assembling particles to minimize energetically costly self-deformations.

Generation of Massively Entangled Bright States of Light during Harmonic Generation in Resonant Media

Sili Yi, Nikolai D. Klimkin, Graham Gardiner Brown, Olga Smirnova, Serguei Patchkovskii, Ihar Babushkin, and Misha Ivanov

Phys. Rev. X **15**, 011023 (2025) - Published 5 February, 2025



High-harmonic generation is generally assumed to be classical. A new analysis shows how quantum correlations can give rise to nontrivial quantum states of harmonic light.

High-Dimensional Quantum Key Distribution by a Spin-Orbit Microlaser

Yichi Zhang, Haoqi Zhao, Tianwei Wu, Zihe Gao, Li Ge, and Liang Feng

Phys. Rev. X **15**, 011024 (2025) - Published 5 February, 2025

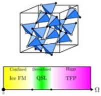
High-Dimensional Secret Key
2 2 3 1 2 0 ...

A first-of-its-kind demonstration of microlaser-enabled, high-dimensional quantum communication relies on multilevel, spin-orbit photon qubits to enhance information capacity and noise resilience.

Quantum Spin Ice in Three-Dimensional Rydberg Atom Arrays

Jeet Shah, Gautam Nambiar, Alexey V. Gorshkov, and Victor Galitski

Phys. Rev. X **15**, 011025 (2025) - Published 6 February, 2025

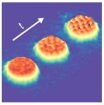


A novel proposal for realizing a type of quantum spin liquid uses 3D Rydberg atom arrays, paving the way to probe a phase of matter that has largely eluded physicists for decades.

Observation of Pattern Stabilization in a Driven Superfluid

Nikolas Liebster, Marius Sparn, Elinor Kath, Jelte Duchene, Keisuke Fujii, Sarah L. Görlitz, Tilman Enss, Helmut Strobel, and Markus K. Oberthaler

Phys. Rev. X **15**, 011026 (2025) - Published 7 February, 2025

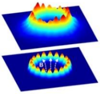


The emergence of square lattice patterns in an otherwise round superfluid of potassium after varying the interactions of its atoms hints at a new state of driven quantum matter.

Necklacelike Pattern of Vortex Bound States

Zhiyong Hou, Kailun Chen, Wenshan Hong, Da Wang, Wen Duan, Huan Yang, Shiliang Li, Huiqian Luo, Qiang-Hua Wang, Tao Xiang, and Hai-Hu Wen

Phys. Rev. X **15**, 011027 (2025) - Published 7 February, 2025



A newly seen magnetic vortex pattern in an iron-based superconductor—neither theoretically predicted nor previously observed—could offer new insights into certain quantum phenomena in superconducting condensates.

FEATURED IN PHYSICS

Multiscale Physics of Atomic Nuclei from First Principles

Z. H. Sun, A. Ekström, C. Forssén, G. Hagen, G. R. Jansen, and T. Papenbrock

Phys. Rev. X **15**, 011028 (2025) - Published 10 February, 2025

A new computational method could help scientists understand the shapes of deformed nuclei from first principles.

FEATURED IN PHYSICS

Entanglement-Enhanced Atomic Gravimeter

Christophe Cassens, Bernd Meyer-Hoppe, Ernst Rasel, and Carsten Klempt

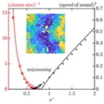
Phys. Rev. X **15**, 011029 (2025) - Published 11 February, 2025

The first measurement of gravity using quantum mechanically entangled atoms demonstrates the potential of the approach.

Self-Consistent Current Response Theory of Unjamming and Vibrational Modes in Low-Temperature Amorphous Solids

Florian Vogel, Philipp Baumgärtel, and Matthias Fuchs

Phys. Rev. X **15**, 011030 (2025) - Published 12 February, 2025

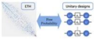


A self-consistent theory of the unjamming transition, applied to a model of amorphous solids described using Euclidean random matrices, elucidates universal vibrational properties.

Designs via Free Probability

Michele Fava, Jorge Kurchan, and Silvia Pappalardi

Phys. Rev. X **15**, 011031 (2025) - Published 12 February, 2025

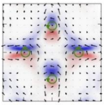


A tool that bridges the gap between *k* designs, which simulate quantum randomness, and quantum chaos and thermalization sheds new light on how quantum systems evolve into randomness.

Imaging Orbital Vortex Lines in Three-Dimensional Momentum Space

T. Figgemeier, M. Ünzelmann, P. Eck, J. Schusser, L. Crippa, J. N. Neu, B. Geldiyev, P. Kagerer, J. Buck, M. Kalläne, M. Hoesch, K. Rossnagel, T. Siegrist, L.-K. Lim, R. Moessner, G. Sangiovanni, D. Di Sante, F. Reinert, and H. Bentmann

Phys. Rev. X **15**, 011032 (2025) - Published 13 February, 2025

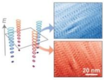


Real-space quantum vortices are key to many phenomena in modern physics. New experiments provide the first proof of vortices in momentum space, raising the prospect of exploring novel orbitronic phenomena.

Valley Polarization of Landau Levels in the ZrSiS Surface Band Driven by Residual Strain

Christopher J. Butler, Masayuki Murase, Shunki Sawada, Ming-Chun Jiang, Daisuke Hashizume, Guang-Yu Guo, Ryotaro Arita, Tetsuo Hanaguri, and Takao Sasagawa

Phys. Rev. X **15**, 011033 (2025) - Published 13 February, 2025



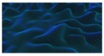
Scanning tunneling microscopy reveals the cause for one kind of electronic symmetry breaking, suggesting avenues for how to exploit it in future, novel devices.

FEATURED IN PHYSICS

Photon-Counting Interferometry to Detect Geontropic Space-Time Fluctuations with GQuEST

Sander M. Vermeulen, Torrey Cullen, Daniel Grass, Ian A. O. MacMillan, Alexander J. Ramirez, Jeffrey Wack, Boris Korzh, Vincent S. H. Lee, Kathryn M. Zurek, Chris Stoughton, and Lee McCuller

Phys. Rev. X **15**, 011034 (2025) - Published 14 February, 2025

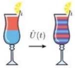


Predictions of theories that combine quantum mechanics with gravity could be observed using highly sensitive photon detection in a tabletop experiment.

Observation of Quantum Thermalization Restricted to Hilbert Space Fragments and Scars

Luheng Zhao, Prithvi Raj Datla, Weikun Tian, Mohammad Mujahid Aliyu, and Huanqian Loh

Phys. Rev. X **15**, 011035 (2025) - Published 18 February, 2025

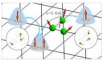


In an out-of-equilibrium Rydberg atom array, chosen subsets of atoms freeze in their initial state, while the rest thermalize, a finding that probes an exotic form of quantum thermalization.

Phonon Thermal Hall Effect in Mott Insulators via Skew Scattering by the Scalar Spin Chirality

Taekoo Oh and Naoto Nagaosa

Phys. Rev. X **15**, 011036 (2025) - Published 19 February, 2025

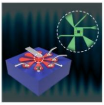


Spins have been long thought to be the primary contributor to the thermal Hall effect in insulators. Theoretical work shows that vibrations can contribute just as much.

Sketched Nanoscale $KTaO_3$-Based Superconducting Quantum Interference Device

Muqing Yu, Nicholas Hougland, Qianheng Du, Junyi Yang, Sayanwita Biswas, Ranjani Ramachandran, Dengyu Yang, Anand Bhattacharya, David Pekker, Patrick Irvin, and Jeremy Levy

Phys. Rev. X **15**, 011037 (2025) - Published 20 February, 2025

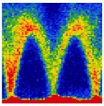


Potassium tantalate enables superconducting weak links with high, tunable inductance, making it a promising material for quantum devices, and its AFM-based nanoscale patterning offers new possibilities for reconfigurable quantum circuits.

Anomalous Quasielastic Scattering Contribution in the Centrosymmetric Multi-q Helimagnet $SrFeO_3$

Nikita D. Andriushin, Justus Grumbach, Anton A. Kulbakov, Yuliia V. Tymoshenko, Yevhen A. Onykiienko, Reza Firouzmandi, Erjian Cheng, Sergey Granovsky, Yurii Skourski, Jacques Ollivier, Helen C. Walker, Vilmos Kocsis, Bernd Büchner, Bernhard Keimer, Mathias Doerr, Dmytro S. Inosov, and Darren C. Peets

Phys. Rev. X **15**, 011038 (2025) - Published 20 February, 2025



$SrFeO_3$, a compound with long-range, helical magnetic order, exhibits unique spin fluctuations that are likely caused by chiral domain walls, making it a valuable material for studying complex magnetic behaviors and spin dynamics.

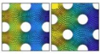
FEATURED IN PHYSICS

Superballistic Conduction in Hydrodynamic Antidot Graphene Superlattices

Jorge Estrada-Álvarez, Juan Salvador-Sánchez, Ana Pérez-Rodríguez, Carlos Sánchez-Sánchez, Vito Clericò, Daniel Vaquero, Kenji Watanabe, Takashi Taniguchi, Enrique Diez, Francisco Domínguez-Adame, Mario Amado, and Elena Díaz

Phys. Rev. X **15**, 011039 (2025) - Published 21 February, 2025

An array of holes in a 2D material enhances an effect that improves the flow of electric currents.



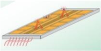
FEATURED IN PHYSICS

Multizone Trapped-Ion Qubit Control in an Integrated Photonics QCCD Device

Carmelo Mordini, Alfredo Ricci Vasquez, Yuto Motohashi, Mose Müller, Maciej Malinowski, Chi Zhang, Karan K. Mehta, Daniel Kienzler, and Jonathan P. Home

Phys. Rev. X **15**, 011040 (2025) - Published 24 February, 2025

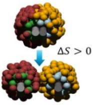
The demonstration that ions can be precisely manipulated in a trap containing integrated photonics paves the way for a large-scale trapped-ion quantum processor.



Chaperone-Driven Entropic Separation of Amyloid Nanofilament Bundles

Jose M. G. Vilar, J. Miguel Rubi, and Leonor Saiz

Phys. Rev. X **15**, 011041 (2025) - Published 24 February, 2025



New insight into how molecular chaperones break apart toxic protein deposits that form amyloid fibrils sheds light on strategies to target these deposits in diseases like Alzheimer's and Parkinson's.

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