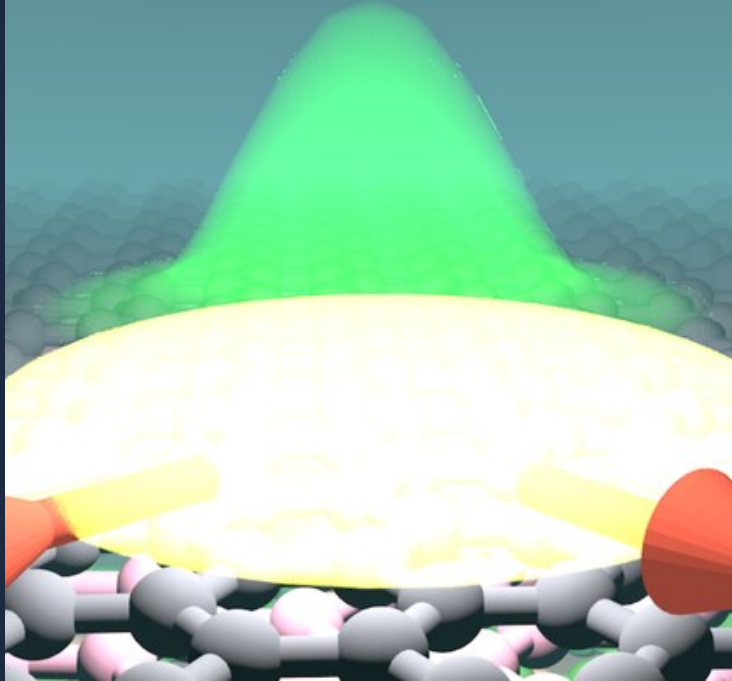




Correlated Quantum Materials

Summary of the group

Aalto University



Group members



Jose L. Lado
ASSISTANT PROFESSOR
Group leader



Adolfo Fumega
RCF RESEARCH FELLOW
van der Waals
multiferroics



Cuiyu Yu
POSTDOC
Optically-driven 2D
materials
co-supervised with Z. Sun



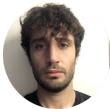
Anouar Moustaj
POSTDOC
Tensor network,
machine learning



Greta Lupi
DOCTORAL RESEARCHER
Machine learning
quantum matter
co-supervised with P.
Liljeroth



Yitao Sun
DOCTORAL RESEARCHER
Machine learning,
out-of-equilibrium
co-supervised with S.
Kezilebieke



Alessandro Orsini
DOCTORAL RESEARCHER
vdW thermoelectrics
and multiferroics
supervised by A. Fumega



Tiago Antão
DOCTORAL RESEARCHER
Out-of-equilibrium
multiferroics
co-supervised with A.
Fumega



Ana Vera
DOCTORAL RESEARCHER
Heavy-fermion vdW
materials
co-supervised with A.
Fumega



Henrik Stenbrink
DOCTORAL RESEARCHER
Twisted vdW
ferroelectrics
co-supervised with M. Caro

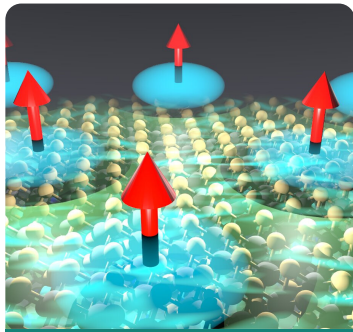


Curie Lee
DOCTORAL RESEARCHER
Spin-liquid/
superconductor



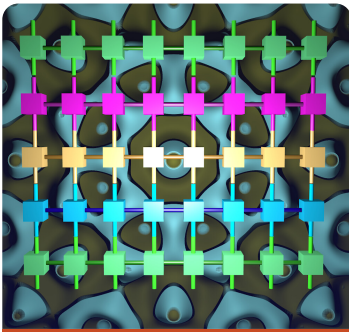
Karoliina Oksanen
DOCTORAL RESEARCHER
Tensor network
super-moiré solvers
co-supervised with A.
Moustaj

Three research lines



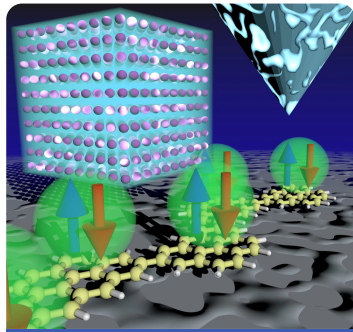
Theory of van der Waals quantum materials

Theoretical material science



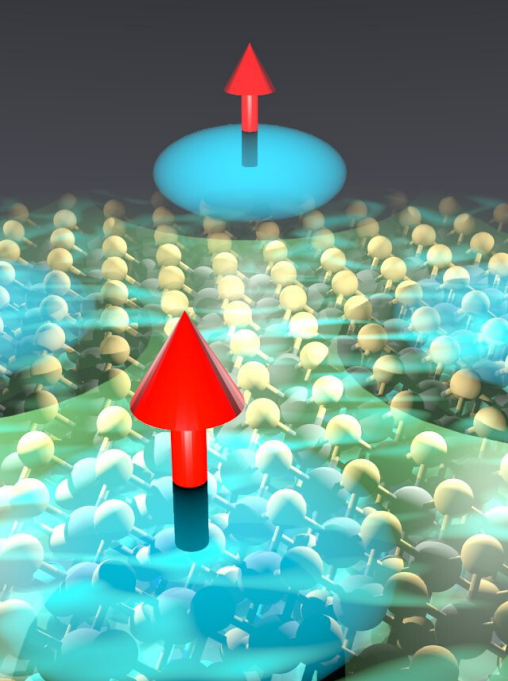
Emergence in quantum many-body physics

Theoretical condensed matter physics



Machine learning quantum materials

Machine learning for quantum technologies

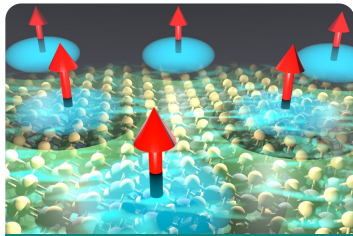


RESEARCH LINE

Theory of van der Waals quantum materials

Stacking, twisting and proximity in van der Waals heterostructures let us engineer states that need antagonistic orders to coexist, and we work with experimental groups to realize them.

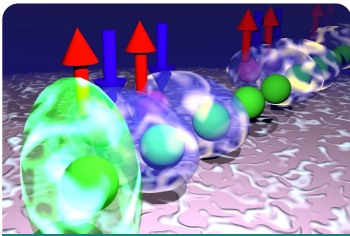
- Heavy fermions in van der Waals materials
- Multiferroics and altermagnets
- Correlated and topological monolayers
- Superconductivity and spin textures



Artificial heavy fermions

A Kondo lattice in a 1T/1H-TaS₂ heterostructure gives a heavy band seen with STM, with P. Liljeroth

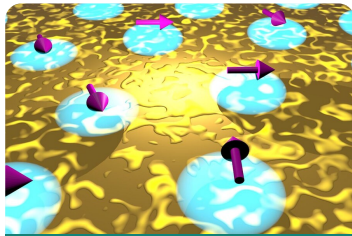
Nature 599, 582 (2021)



Topological Kondo lattices

Topological zero modes driven by collective Kondo physics, solved with tensor networks

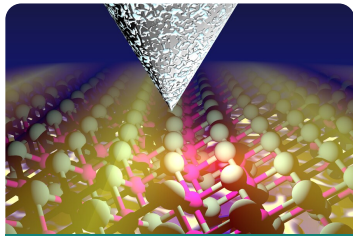
Phys. Rev. Lett. 134, 116605 (2025)



Monolayer heavy fermions

Monolayer CeSi₃ hosts an unconventional heavy-fermion Kondo state

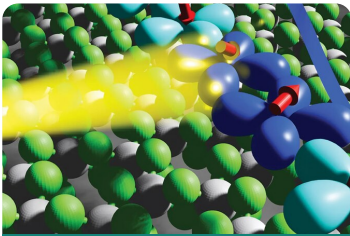
Nano Lett. 24, 4272 (2024)



Multiferroic order at the atomic scale

Coupled magnetic and polar order of monolayer NiI_2 imaged with STM, with P. Liljeroth

Adv. Mater. 36, 2311342 (2024)

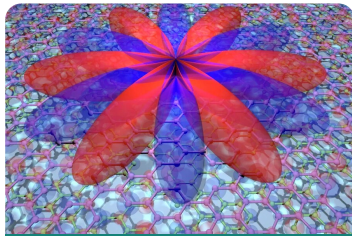


Magneto-orbital order

Spin and orbital order of monolayer VCl_3 give rise to magneto-orbital excitations

Journal cover

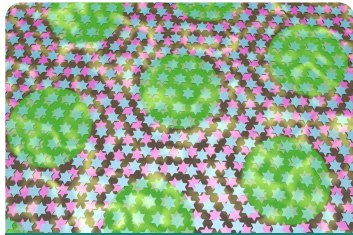
Nano Lett. 25, 4825 (2025)



i-wave altermagnetism in carbon

Graphene antidot superlattices designed by symmetry into *i*-wave altermagnets

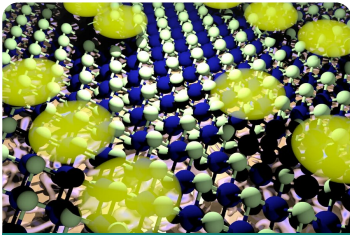
Adv. Sci. e78167 (2026)



Moiré Mott mosaics

Twisting 1T-TaS₂ bilayers creates a mosaic of Mott and trivial insulating regions

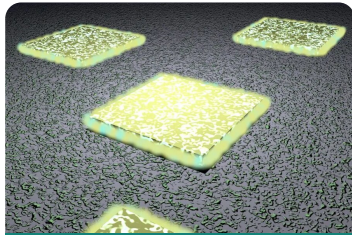
Nano Lett. (2026)



Doped Mott insulator

Doping and charge correlations of the Mott state of monolayer 1T-NbSe₂, with P. Liljeroth

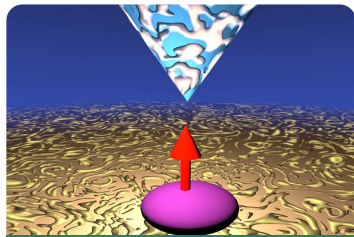
Phys. Rev. Lett. 134, 046504 (2025)



Strain-driven topology

Strain turns bilayer SnTe into a 2D topological crystalline insulator, with S. Kezilebieke

Nat. Commun. 17, 817 (2026)

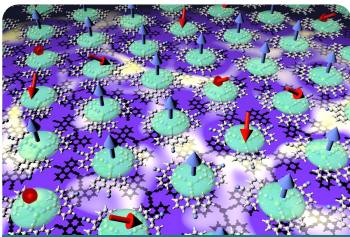


Andreev reflection through one orbital

A molecular orbital tunes Andreev reflection, with J. Kröger

PRL Collection of the Year 2025
Editors' Suggestion, Featured in Physics

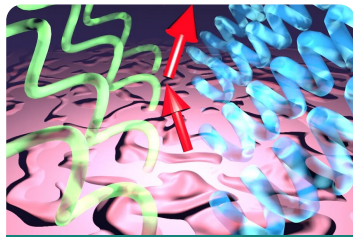
Phys. Rev. Lett. 134, 146201 (2025)



Spin textures on a superconductor

Molecular complexes on a 2D superconductor form an exotic spin texture, with P. Liljeroth

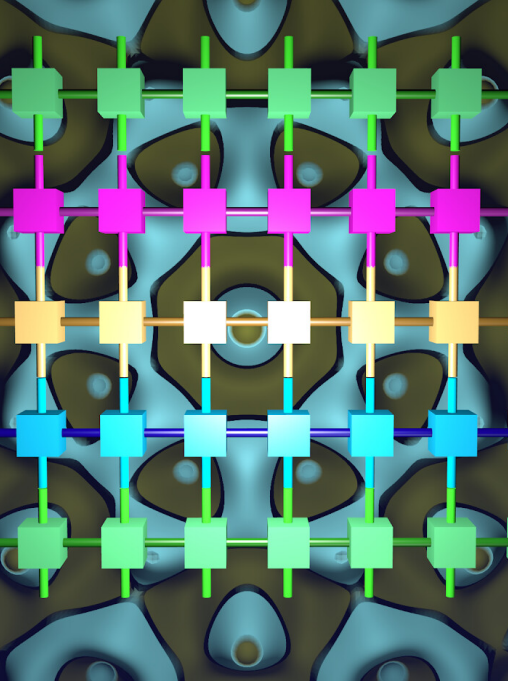
Phys. Rev. Lett. 133, 236203 (2024)



Chiral spin textures with light

Nonlinear optics reveals tunable chiral spin textures, with Z. Sun

Nat. Commun. 17, 7576 (2026)

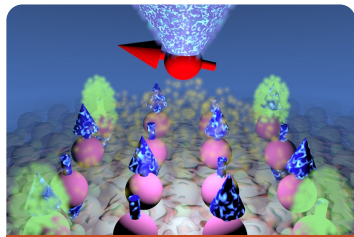


RESEARCH LINE

Emergence in quantum many-body physics

Interactions, dissipation and quasiperiodicity give rise to quantum matter with no single-particle counterpart, and we develop the tensor-network methods to solve it.

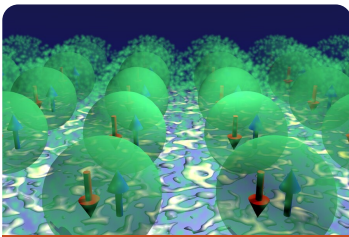
- Topological quantum magnets atom by atom
- Molecular quantum magnets
- Non-Hermitian quantum matter
- Tensor networks for ultra-large quantum matter



Topological magnets from atomic spins

Atomic spins on a surface assembled into a topological quantum magnet, with K. Yang

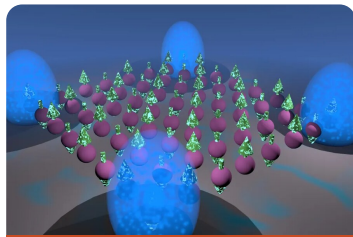
Nat. Nanotechnol. 19, 1782 (2024)



Imaging triplons

Triplon excitations of an engineered quantum magnet imaged in real space, with P. Liljeroth

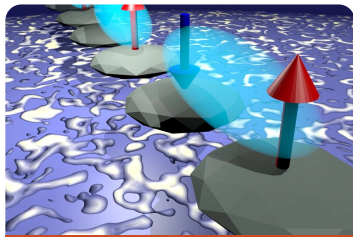
Phys. Rev. Lett. 131, 086701 (2023)



Second-order topological magnets

Phase diagram of the J_1 - J_2 Heisenberg second-order topological quantum magnet

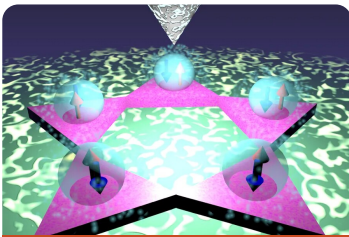
Phys. Rev. Research 7, 013194 (2025)



Spin-1/2 molecular chains

Heisenberg antiferromagnetic chains synthesized on a surface, with S. Kawai

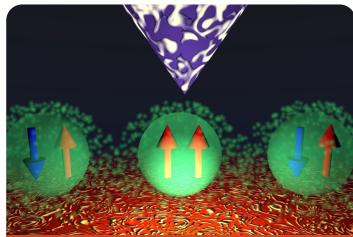
Sci. Adv. 11, eads1641 (2025)



Frustrated molecular rings

Frustration gives rise to a many-body degeneracy in spin-1/2 rings, with S. Kawai

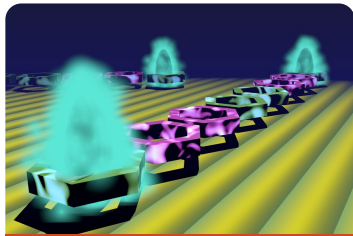
J. Am. Chem. Soc. 147, 26208 (2025)



Tip-induced isomerization

A local probe switches the structure of a one-dimensional molecular array, with S. Kawai

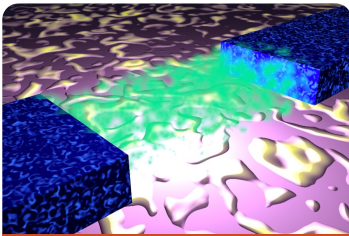
Nat. Commun. 14, 7741 (2023)



Topology from optical losses

Engineered losses give non-Hermitian topology in photonic lattices, with
A. Blanco-Redondo

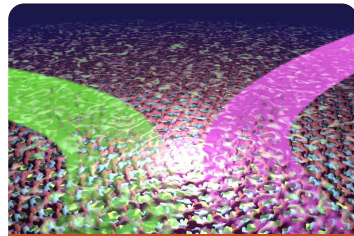
Nat. Mater. 24, 1393 (2025)



Non-Hermitian Fermi-Dirac

Dissipative persistent currents written in terms of the complex spectrum alone

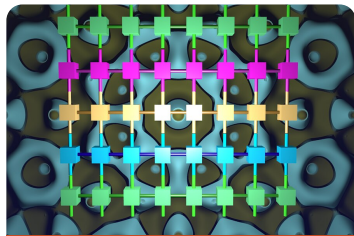
Phys. Rev. Lett. 133, 086301 (2024)



Non-Hermitian valley filter

A valley-resolved skin effect in strained moiré bilayers filters the valleys

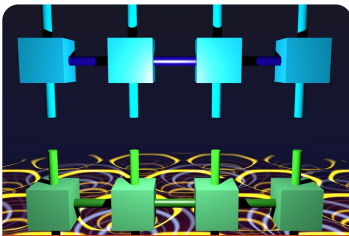
Phys. Rev. Lett. 132, 156301 (2024)



Quasicrystal Chern mosaics

Real-space topology of quasicrystals computed with tensor networks

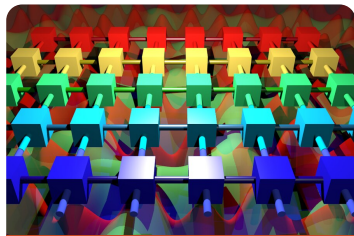
Phys. Rev. Lett. 136, 156601 (2026)



Beyond one billion sites

Correlated super-moiré matter solved self-consistently beyond a billion sites

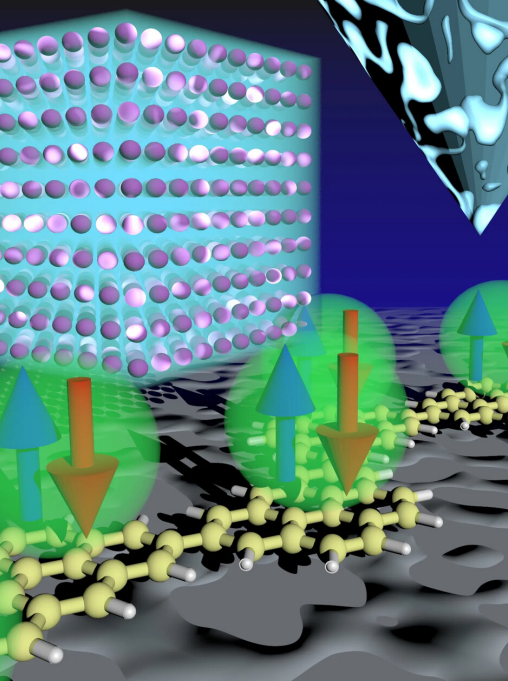
Phys. Rev. Research 7, 043288 (2025)



Multi-scale Gross-Pitaevskii

Quantics tensor trains solve the Gross-Pitaevskii equation across scales, with X. Waintal

Phys. Rev. Research 8, 023006 (2026)

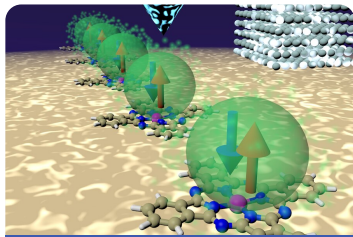


RESEARCH LINE

Machine learning quantum materials

Machine learning brings experimental data and quantum many-body models together, with learning the Hamiltonian of a material from its measurements as the central problem.

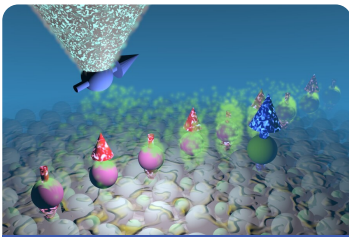
- Hamiltonian learning from STM
- Machine learning for quantum devices
- Learning correlations and entanglement
- Learning materials from experiments



Learning triplons

The Hamiltonian of a molecular quantum magnet learned from STM, with P. Liljeroth

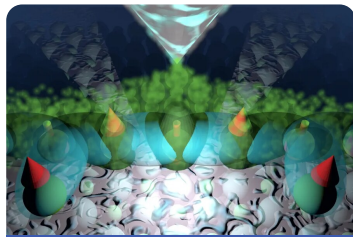
[Nano Lett. 25, 13435 \(2025\)](#)



Non-local impurity tomography

Hamiltonian parameters learned from impurity-induced ground-state fluctuations

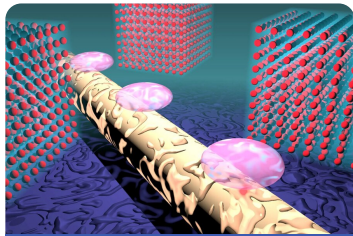
[Phys. Rev. Applied 23, 054077 \(2025\)](#)



Dynamical impurity tomography

Quantum magnets learned from the dynamical response around impurities

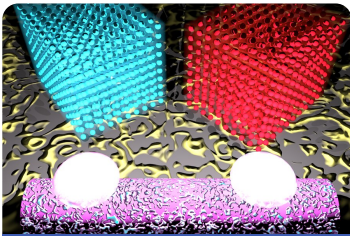
[Phys. Rev. Research 8, 033281 \(2026\)](#)



Autonomous Kitaev chains

Tuned by machine learning across platforms, with L. Kouwenhoven and E. Greplova

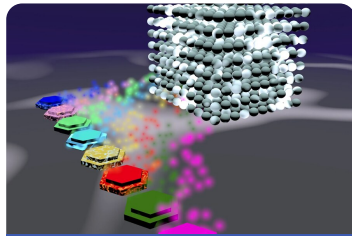
[PRX Intelligence 1, 013005 \(2026\)](#)



Adversarial Hamiltonian learning

Adversarial networks learn the Hamiltonian of quantum dots in a minimal Kitaev chain

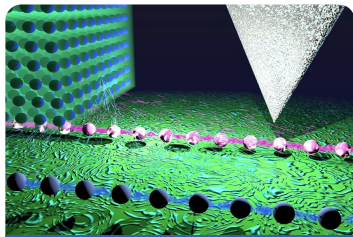
[Phys. Rev. Applied 20, 044081 \(2023\)](#)



Photonic ring resonators

Single resonators characterized inside a photonic lattice, with A. Blanco-Redondo

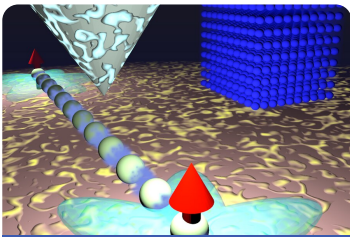
[APL Photonics 11, 076124 \(2026\)](#)



Correlation entropy

Transfer learning of the many-body correlation entropy from local measurements, with T. Ojanen

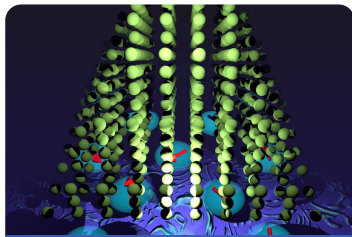
Phys. Rev. Applied 24, 054014 (2025)



Kondo entanglement cloud

The Kondo cloud learned from local measurements

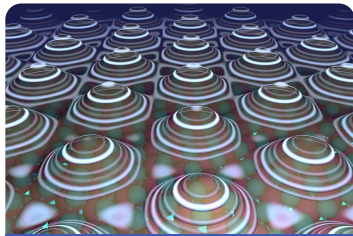
Phys. Rev. B 109, 195125 (2024)



Lee-Yang with neural networks

Quantum phase transitions located with neural-network quantum states, with C. Flindt

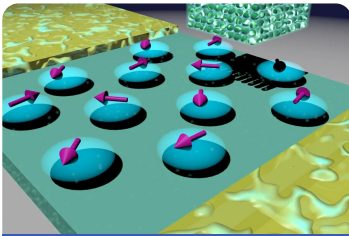
Phys. Rev. Research 5, 033116 (2023)



Charge density waves

Machine-learned interatomic potentials for the charge density wave of NbSe₂

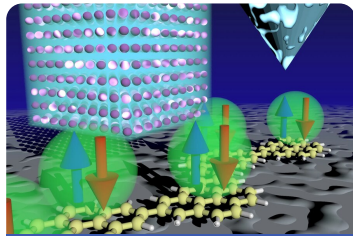
[npj Comput. Mater. 12, 239 \(2026\)](#)



Moiré magnets from transport

Spin-spiral Hamiltonians learned from magnetotransport, with Z. Sun

[arXiv:2604.02959 \(2026\)](#)



Nanographene spin chains

Inhomogeneous Heisenberg chains learned from STM, with R. Fasel

[arXiv:2606.29281 \(2026\)](#)