Focus session title
From disorder to metastability and hidden phases in 2D quantum materials

Focus session synopsis
Technologically relevant complex behaviors in systems with reduced dimensionality are typically associated with disorder and frustration due to competing interactions, often leading to various subtle forms of intrinsic short-range order as well as external stimuli-induced hidden metastable states. These behaviors span a wide range of theoretical and experimental challenges in systems that host a rich variety of exotic phases, unusual quasiparticle excitations, and non-equilibrium dynamics, where fundamental issues remain elusive. This session aims to provide a forum for these fascinating phenomena, highlighting diverse characterization methods and novel theoretical approaches, and to give an overview of recent observations and advances. It will discuss open questions whose understanding may be essential for propelling quantum materials science and unlocking the potential for quantum technologies.

Sessions Topics Include (but not limited to):

- Impact of disorder on competing orders in electronic systems
- Geometric frustration and short-range order driven phenomena
- Glassy dynamics vs. pre-thermal regimes of correlated electrons
- Hidden and metastable states and their manipulation

Focus session invited speakers (all tentatively confirmed)

Dr. Dragana Popovic
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Reason for invitation:
Dr. Popovic is a seasoned experimental condensed matter physicist with expertise in effects of disorder and strong electronic correlations in two-dimensional (2D) and quasi-2D systems, primarily using electrical transport and resistance noise spectroscopy techniques. Her topics of interest include phase transitions (metal-insulator, superconductor-insulator, structural, and Berezinskii-Kosterlitz-Thouless transitions), charge dynamics (glassy freezing and other out-of-equilibrium behavior), superconducting fluctuations, mesoscopic effects. Materials that are focus of her research include semiconductor heterostructures, layered transition-metal dichalcogenides, copper-oxide high-temperature superconductors, iron pnictides, and quasicrystals. She will present work on "Screening the Coulomb interaction leads to a prethermal regime in two-dimensional bad conductors" published in Nature Communications 14, 7004 (2023).

Recent few important/digested publications:
The interplay of disorder, interactions, and quantum mechanics has been of great interest as it gives rise to a variety of complex phenomena [1]. The most intriguing aspect is the breakdown of ergodicity, which generally leads to very slow dynamics, such as glassiness and many-body localization (MBL) [2], especially in low dimensions. In electronic systems, glassy dynamics has been studied in thin films of some disordered insulators (e.g. [3] and refs. therein), two-dimensional electron system (2DES) in Si heterostructures near the metal-insulator transition ([4, 5] and refs. therein), and lightly doped cuprates (e.g. [6, 7]), but many questions remain open. On the other hand, experimental studies of MBL, which is

of great interest for quantum information science, have been limited to those on synthetic quantum matter, such as ultracold atoms in optical lattices and superconducting qubits, while observing the absence of thermalization in real, solid-state materials has been a challenge [2]. A recent study of charge dynamics in a 2DES with a screened Coulomb interaction has provided the first direct observation of a MBL, prethermal regime in an electronic system [8]. By establishing a new, versatile solid-state platform for studies of thermalization and MBL in large systems, that work also opens new possibilities for further studies of ergodicity breaking and quantum entanglement in real materials.

[1] L. F. Cugliandolo and M. Müller, Quantum Glasses. https://arxiv.org/abs/2208.05417v2 (2022; to appear in "Spin Glass Theory and Far Beyond - Replica Symmetry Breaking after 40 years").
[2] D. A. Abanin, E. Altman, I. Bloch, and M. Serbyn, *Colloquium:* Many-body localization, thermalization, and entanglement. Rev. Mod. Phys. **91**, 021001 (2019).
[3] J. Delahaye and T. Grenet, Electron glass signatures up to room temperature in disordered insulators. J. Phys.: Condens. Matter **34**, 135603 (2022).
[4] D. Popović, "Glassy Dynamics of Electrons Near the Metal-Insulator Transition", chapter in *Conductor-Insulator Quantum Phase Transitions*, edited by V. Dobrosavljevic, N. Trivedi, and J. Valles, Jr. (Oxford University Press, USA, 2012).
[5] D. Popović, "Metal-Insulator Transition in Correlated Two-Dimensional Systems with Disorder", chapter in *Strongly Correlated Electrons in Two Dimensions*, edited by S. V. Kravchenko (Pan Stanford Publishing Pte. Ltd, Singapore, 2017).
[6] I. Raičević, J. Jaroszyński, D. Popović, C. Panagopoulos, and T. Sasagawa, Evidence for Charge Glasslike Behavior in Lightly Doped $La_{2-x}Sr_xCuO_4$. Phys. Rev. Lett. **101**, 177004 (2008).
[7] X. Shi, G. Logvenov, A. T. Bollinger, I. Božović, C. Panagopoulos, and D. Popović. Emergence of superconductivity from the dynamically heterogeneous insulating state in $La_{2-x}Sr_xCuO_4$. Nat. Mater. **12**, 47 (2013).
[8] L. J., Stanley, L.J.; P. V. Lin, J. Jaroszyński, and D. Popović, Screening the Coulomb interaction leads to a prethermal regime in two-dimensional bad conductors. Nat. Commun. **14**, 7004 (2023).

Other relevant publications include:

Maccari, I.; Pokharel, B.K.; Terzic, J.; Dutta, S.; Jesudasan, J.; Raychaudhuri, P.; Lorenzana, J.; De Michele, C.; Castellani, C.; Benfatto, L.; Popovic, D., Transport signatures of fragile glass dynamics in the melting of the two-dimensional vortex lattice, Physical Review B, 107, 014509 (2023) https://doi.org/10.1103/PhysRevB.107.014509

Pokharel, B.K.; Wang, Y.; Jaroszynski, J.J.; Sasagawa, T.; Popovic, D., Charge-order dynamics in underdoped La1.6−xNd0.4SrxCuO4 revealed by electric pulses, Applied Physics Letters, 118, 244104 (2021) https://doi.org/10.1063/5.0055413

Shi, Z.; Baity, P.G.; Terzic, J.; Pokharel, B.K.; Sasagawa, T.; Popovic, D., Magnetic field reveals vanishing Hall response in the normal state of stripe-ordered cuprates, Nature Communications, 12, 3724 (2021) https://doi.org/10.1038/s41467-021-24000-3

Stanley, L.J.; Chuang, H.J.; Zhou, Z.; Koehler, M.R.; Yan, J.; Mandrus, D.G.; Popovic, D., Low-temperature 2D/2D Ohmic contacts in WSe2 field-effect transistors as a platform for the 2D metal-insulator transition, American Chemical Society Applied Materials and Interfaces, 13, 10594 (2021) https://doi.org/10.1021/acsami.0c21440

Shi, Z.; Baity, P.G.; Terzic, J.; Sasagawa, T.; Popovic, D., Pair density wave at high magnetic fields in cuprates with charge and spin orders, Nature Communications, 11, 3323 (2020) https://doi.org/10.1038/s41467-020-17138-z

Shi, Z.; Baity, P.G.; Sasagawa, T.; Popovic, D., Vortex phase diagram and the normal state of cuprates with charge and spin orders, Science Advances, 6, eaay8946 (2020) https://doi.org/10.1126/sciadv.aay8946

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Reason for invitation:

Dr. Dobrosavljevic is one of the leading Condensed Matter Science theorists, applying dynamical mean-field theory (DMFT) approaches to Anderson localization effects, localization-induced Griffiths phases leading to non-Fermi liquid (and/or spin liquid) metallic behavior, and has been developing theoretical framework describing how glassy behavior of electrons emerges in the vicinity of disorder-driven metal-insulator transitions.

The subject of metal-insulator transitions came to a renewed focus in the twenty-five years, following the discovery of high temperature superconductivity, which triggered much activity in the study of “bad metals”. Many of the materials in this family consist of transition metal or even rare earth elements, corresponding to compounds which are essentially on the brink of magnetism. Here, conventional approaches proved of little help, but recent research has led to a veritable avalanche of new and exciting ideas and techniques both on the experimental and the theoretical front. In the last twelve years, a systematic new approach to strong correlations has been developed, based on DMFT methods. Their recent results have demonstrated that all the basic localization mechanisms and processes can be described within extended DMFT framework, and have produced a number of results of direct experimental relevance, including Theory for Anderson localization effects in presence of strong correlations, Description of localization-induced Griffiths phases leading to non-Fermi liquid (and/or spin liquid) metallic behavior, and theory describing how glassy behavior of electrons emerges in the vicinity of disorder-driven metal-insulator transitions.

Some of the subjects that Prof. Dobrosavljevic has introduced have, in the last few years, become topics of central interest and much activity. This is especially true for glassy phenomena that emerge in many electronic systems with disorder. This direction for research offers a great deal of promise and will continue to attract increased attention in the coming years. Materials where these phenomena are of central importance are surprisingly numerous, ranging from two-dimensional electron gases in MOSFETs, diluted magnetic semiconductors, CMR manganites and high Tc cuprates. Their theoretical approaches are very flexible and useful tools that should play a central role in this emerging field.

Recent few important/digested publications:

In his work on metal-insulator transitions in correlated and disordered systems, lately he's been focusing a lot on situations where charge ordering (i.e. Wigner crystallization) plays an important role. This was

very well seen in various TMD systems, e.g. in works of Prof. Dr. Dragan Mihailovic. However, similar physics was seen in TMD moiré materials, which Prof. Dobrosavljevic described in their publication on Wigner-Mott-Glass behavior:
"Doping a Wigner-Mott insulator: Exotic charge orders in transition metal dichalcogenide moiré heterobilayers" Phys. Rev. Research 5, 043190 (2023).

There they revealed "competing charge orders" due to geometric frustration, and this can lead, in addition to periodic arrangement, to "glassy" behavior, where only short-range order, silicon like the range seen in the so-called theta-organic materials, about which they described in earlier publication:
"Glassy Dynamics in Geometrically Frustrated Coulomb Liquids without Disorder" Phys. Rev. Lett. 115, 025701 (2015)

As for the regime where there is no Wigner-Mott physics, but disorder seems to dominate the MIT behavior, they recently published the following paper about it, also on TMD moiré materials:
"Disorder-dominated quantum criticality in moiré bilayers" Nature Communications 13, 7469 (2022)

Other relevant publications include:
Prof. Dobrosavljevic and his team at the National High Magnetic Field Laboratory who study materials' electronic properties are applying their techniques at a colossal scale to help solve a puzzle deep within the Earth. Under some extreme conditions, they showed that one gets really big surprises where even at very high temperatures, one can reveal quantum effects. The pressure seems to be a key factor in making that possible in FeO at the higher temperatures. This work was published in:
“Quantum critical phase of FeO spans conditions of Earth’s lower mantle”
Nature Communications 15, 3461 (2024)

Professor Dr. Benjamin Frandsen
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Reason for invitation:
Prof. Frandsen is an emerging world-class leader in Experimental Condensed Matter Physics--Investigating the local structure and magnetism of advanced quantum materials using particle beams of x-rays, neutrons, and muons at large-scale accelerator facilities. He has pioneered total scattering based magnetic atomic pair distribution function (mPDF) methodology that has revolutionized studies of short-range magnetic order in quantum matter, complementing his expertise in muon spin rotation (muSR) characterizations.

Dr. Frandsen’s experimental condensed matter physics group is focused on investigating the structure and magnetism of fascinating--and often technologically promising--materials, such as superconductors, strongly correlated electron systems, multiferroics, magnetocalorics, molten salts for nuclear reactors, and more. They use beams of neutrons, x-rays, and muons produced at large-scale accelerator facilities to probe the atomic and magnetic correlations in these materials, together with advanced computational modeling to gain quantitative insight into the spatial arrangement of atoms and spins in a given material. Specific techniques include atomic and magnetic pair distribution function (PDF) analysis of neutron/x-ray total scattering data and muon spin relaxation/rotation (μSR). His projects span diverse materials and phenomena including among others thermoelectrics, magnetocalorics, multiferroics, high temperature superconductors, geometrically frustrated magnets, and magnetic nanoparticles.

Recent few important/digested publications:

"A New Spin on Material Properties: Local Magnetic Structure in Functional and Quantum Materials"
Chemistry of Materials 36, 9089 (2024) – Perspective article

The past few decades have made clear that the properties and performances of emerging functional and quantum materials can depend strongly on their local atomic and/or magnetic structure, particularly when details of the local structure deviate from the long-range structure averaged over space and time. Traditional methods of structural refinement (e.g., Rietveld) are typically sensitive only to the average structure, creating a need for more advanced structural probes suitable for extracting information about structural correlations on short length- and time-scales. In this Perspective, Dr. Frandsen and his team describe the importance of local magnetic structure in several classes of emerging materials and present the magnetic pair distribution function (mPDF) technique as a powerful tool for studying short-range magnetism from neutron total-scattering data. They then provide a selection of examples of mPDF analysis applied to magnetic materials of recent technological and fundamental interest, including the antiferromagnetic semiconductor MnTe, geometrically frustrated magnets, and iron-oxide magnetic nanoparticles. The rapid development of mPDF analysis since its formalization a decade ago puts this technique in a strong position for making continued impact in the study of local magnetism in emerging materials.

"Giant Spontaneous Magnetostriction in MnTe Driven by a Novel Magnetostructural Coupling Mechanism"
Advanced Functional Materials 33, 2305247 (2023)

A comprehensive x-ray scattering study of spontaneous magnetostriction in hexagonal MnTe, an antiferromagnetic semiconductor with a Néel temperature of T_N = 307 K, is presented. The largest spontaneous magnetovolume effect known for an antiferromagnet is observed, reaching a volume contraction of $|\Delta V/V| > 7 \times 10^{-3}$. This can be justified semiquantitatively by considering bulk material properties, the spatial dependence of the superexchange interaction, and the geometrical arrangement of magnetic moments in MnTe. The highly unusual linear scaling of the magnetovolume effect with the short-range magnetic correlations, beginning in the paramagnetic state well above T_N, points to a novel physical mechanism, which is explained in terms of a trilinear coupling of the elastic strain with superposed distinct domains of the antiferromagnetic order parameter. This novel mechanism for coupling lattice strain to robust short-range magnetic order casts new light on magnetostrictive phenomena and also provides a template by which the exceptional magnetostrictive properties of MnTe might be realized in a wide range of other functional materials.

"Real-space visualization of short-range antiferromagnetic correlations in a magnetically enhanced thermoelectric", Matter 5, 1853 (2022)

Short-range magnetic correlations can significantly increase the thermopower of magnetic semiconductors, representing a noteworthy development in the decades-long effort to develop high-performance thermoelectric materials. Here, they reveal the nature of the thermopower-enhancing magnetic correlations in the antiferromagnetic semiconductor MnTe. Using magnetic pair distribution function analysis of neutron-scattering data, they obtain a detailed, real-space view of robust, nanometer-scale, antiferromagnetic correlations that persist into the paramagnetic phase above the Néel temperature T_N = 307 K. The magnetic correlation length in the paramagnetic state is significantly longer along the crystallographic *c* axis than within the *ab* plane, pointing to anisotropic magnetic interactions. *Ab initio* calculations of the spin-spin correlations using density functional theory in the disordered local moment approach reproduce this result with quantitative accuracy. These findings constitute the first real-space picture of short-range spin correlations in a magnetically enhanced thermoelectric and inform future efforts to optimize thermoelectric performance by magnetic means.

“Effect of iron vacancies on magnetic order and spin dynamics of the spin ladder $BaFe_{2-\delta}S1.5Se_{1.5}$”
Phys. Rev. B 105, 214303 (2022)
Quasi-one-dimensional iron chalcogenides possess various magnetic states depending on the lattice distortion, electronic correlations, and presence of defects. They presented neutron diffraction and inelastic neutron scattering experiments on the spin ladder compound BaFe2−δS1.5Se1.5 with ∼6% iron vacancies. The data reveal that long-range magnetic order is absent, while the characteristic magnetic excitations that correspond to both the stripe- and block-type antiferromagnetic correlations are observed. First-principles calculations support the existence of both stripe- and block-type antiferromagnetic short-range orders in the experimental sample. They speculate that disappearance of long-range magnetic order may be due to the competition between these two magnetic orders, which is greatly enhanced for a certain concentration of iron vacancies, which we calculate to be about 6%, consistent with the measured iron vacancy concentration. Their results highlight how iron vacancies in the iron-based spin ladder system strongly influence the magnetic ground state.

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Reason for invitation:
Qiang Li’s Quantum Materials Physics group is primarily focused on physics and applications of quantum materials in energy and quantum information systems. This group uses a combined materials synthesis, characterization and theoretical modeling approach to explore quantum states of matter. Synthesis effort includes single crystal and epitaxial film growth of a variety of quantum materials from superconductors to topological semimetals/insulators, and high-pressure synthesis of novel materials. Multiple characterization techniques are used in his group to characterize transport and thermodynamic properties of quantum materials under various external stimuli, such as light, temperature, magnetic field, pressure and in-situ tunable strain. Photon and electron spectroscopic experiments, some of which are carried out at national synchrotron light sources, are performed to explore electron and phonon band structures. Theoretical modeling uses first-principles and effective Hamiltonian methods. Recently, his group has been particularly interested in understanding and control of topological phase transitions and unconventional superconductivity, with an increased effort in quantum device fabrication and characterizations. The development of scalable superconducting and thermoelectric materials and devices is a longstanding effort of this group for applications in next generation of electric machines, electricity transmission, energy conversion and storage.

Recent few important/digested publications:
“Origin of light-induced metastability in ZrTe5”
Physical Review B 110 (11), 115128 (2024)
Dr. Li and his team studied the nonequilibrium electronic structure of a model Dirac semimetal ZrTe5 by using time-and-angle resolved photoemission spectroscopy and density functional theory–based electron and phonon calculations. By measuring the electronic dispersion near the Γ point at time delays up to 10 picoseconds, they discovered that the band spectral weight does not recover during the measured temporal window, revealing the existence of a light-induced metastable state in the electronic structure of this material. Their calculations fond that the photoexcited $A1g$ phonon mode leads to a band renormalization that both supports our experimental observations at the zone center and predicts changes to the band structure outside of our experimental window, ultimately showing the evolution

from a direct to an indirect gap semimetal; such band renormalization dramatically reduces the electron-hole recombination rate giving rise to the metastability in this system.

"Verwey transition as evolution from electronic nematicity to trimerons via electron-phonon coupling"
Science Advances 9, eadf8220 (2023)
Understanding the driving mechanisms behind metal-insulator transitions (MITs) is a critical step toward controlling material's properties. Since the proposal of charge order–induced MIT in magnetite Fe3O4 in 1939 by Verwey, the nature of the charge order and its role in the transition have remained elusive. Recently, a trimeron order was found in the low-temperature structure of Fe3O4; however, the expected transition entropy change in forming trimeron is greater than the observed value, which arises a reexamination of the ground state in the high-temperature phase. Here, they use electron diffraction to unveil that a nematic charge order on particular Fe sites emerges in the high-temperature structure of bulk Fe3O4 and that, upon cooling, a competitive intertwining of charge and lattice orders arouses the Verwey transition. Their findings discover an unconventional type of electronic nematicity in correlated materials and offer innovative insights into the transition mechanism in Fe3O4 via the electron-phonon coupling.

Other relevant publications include:

"A light-induced phononic symmetry switch and giant dissipationless topological photocurrent in ZrTe5"
Luo L, Cheng D, Song B, Wang L-L, Vaswani C, Lozano PM, Gu G, Huang C, Kim RHJ, Liu Z, Park J-M, Yao Y, Ho K, Perakis IE, Li Q, Wang J, Nature Materials 20, 329 (2021). doi: 10.1038/s41563-020-00882-4

"Observation and control of the weak topological insulator state in ZrTe5"
Zhang P, Noguchi R, Kuroda K, Lin C, Kawaguchi K, Yaji K, Harasawa A, Lippmaa M, Nie S, Weng H, Kandyba V, Giampietri A, Barinov A, Li Q, Gu GD, Shin S, Kondo T Nature Communications 12, 406 (2021). doi: 10.1038/s41467-020-20564-8

"Experimental evidence that zinc impurities pin pair-density-wave order in La2−xBaxCuO4"
Lozano PM, Gu GD, Tranquada JM, Li Q, Physical Review B 103, L020502 (2021).
doi: 10.1103/physrevb.103.l020502

"Topological Phase Transition and Phonon-Space Dirac Topology Surfaces in ZrTe5"
Aryal N, Jin X, Li Q, Tsvelik AM, Yin W, Physical Review Letters 126, 016401 (2021).
doi: 10.1103/physrevlett.126.016401

"Unconventional Hall response in the quantum limit of HfTe5"
Galeski S, Zhao X, Wawrzynczak R, Meng T, Förster T, Lozano PM, Honnali S, Lamba N, Ehmcke T, Markou A, Li. Q, Gu G, Zhu W, Wosnitza J, Felser C, Chen GF, Gooth J, Nature Communications 11, 5926 (2020). doi: 10.1038/s41467-020-19773-y

"Light-Driven Raman Coherence as a Nonthermal Route to Ultrafast Topology Switching in a Dirac Semimetal", Vaswani C, Wang L-L, Mudiyanselage DH, Li Q, Lozano PM, Gu GD, Cheng D, Song B, Luo L, Kim RHJ, Huang C, Liu Z, Mootz M, Perakis IE, Yao Y, Ho KM, Wang J, Physical Review X 10, 021013 (2020). doi: 10.1103/physrevx.10.021013

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Reason for invitation:

Igor Vaskivskyi is researching correlated electronic materials and developing new methods in the field of time-resolved spectroscopy in the extreme UV (EUV) range. He is interested in revealing the properties and reasons for metastability in electronic crystals and controlling magnetic orders in crystals and thin films. They explore non-equilibrium many-body dynamics in quantum systems that experience symmetry-breaking, topological, or jamming transitions. These systems encompass superconductors, charge-density wave systems, magnetic materials and heterostructures.

Dr. Vaskivskyi and their team are developing new methods for studying the dynamics of complex magnetic materials in 3D and on ultrafast time scales. Utilizing lab-scale laser sources, they have recently built the compact beamline, which provides unique insight into the dynamics of magnetic moments of separate species within a composite system beyond the typical “single-projection” approach. With the new capabilities, they are investigating the prospects for magnetization reversal and the details of magnetization dynamics in technologically relevant ferromagnetic films with high anisotropy. Additionally, based on their recent discovery of extremely fast laser-triggered lattice reconfiguration in a layered charge-ordered material they are developing the first-ever ultra-efficient tunable light modulator, which works in extreme UV and soft X-ray spectral range. They are investigating the mechanisms for unusually strong lattice deformation, which accompanies the laser-induced electronic phase transition and methods for implementing phenomena in the shape of a full-fledged spatial light modulator. Dr. Vaskivskyi would be an ideal contributor to the topic of hidden phases and their manipulation, such as lattice reconfiguration driven by metastable electronic phase transition in TMDs.

Recent few important/digested publications:

"A high-efficiency programmable modulator for extreme ultraviolet light with nanometre feature size based on an electronic phase transition"
Nature Photonics 18, 458 (2024)
The absence of efficient light modulators for extreme ultraviolet (EUV) and X-ray photons considerably limits their real-life application, particularly when even slight complexity of the beam patterns is required. In this publication they report on a novel approach to reversible imprinting of a holographic mask in an electronic Wigner crystal material with a sub-90-nm feature size. The structure is imprinted on a sub-picosecond timescale using EUV laser pulses, and acts as a high-efficiency diffraction grating that deflects EUV or soft X-ray light. The imprinted nanostructure is stable after the removal of the exciting beams at low temperatures, but can be easily erased by a single heating beam. Modelling shows that the efficiency of the device can exceed 1%, approaching state-of-the-art etched gratings, but with the benefit of being programmable and tunable over a large range of wavelengths. The observed effect is based on the rapid change of lattice constant upon transition between metastable electronically ordered phases in a layered transition metal dichalcogenide. The proposed approach is potentially useful for creating tunable light modulators in the EUV and soft X-ray spectral ranges.

"Manipulation of fractionalized charge in the metastable topologically entangled state of a doped Wigner crystal"
Nature Communications 14, 8214 (2023)
Metastability of many-body quantum states is rare and still poorly understood. An exceptional example is the low-temperature metallic state of the layered dichalcogenide 1T-TaS2 in which electronic order is frozen after external excitation. In this work they visualize the microscopic dynamics of injected charges in the metastable state using a multiple-tip scanning tunnelling microscope. They observe non-thermal formation of a metastable network of dislocations interconnected by domain walls, that leads to

macroscopic robustness of the state to external thermal perturbations, such as small applied currents. With higher currents, they observe annihilation of dislocations following topological rules, accompanied with a change of macroscopic electrical resistance. Modelling carrier injection into a Wigner crystal reveals the origin of formation of fractionalized, topologically entangled networks, which defines the spatial fabric through which single particle excitations propagate. The possibility of manipulating topological entanglement of such networks suggests the way forward in the search for elusive metastable states in quantum many body systems.

Other relevant publications include:

"A time-domain phase diagram of metastable states in a charge ordered quantum material"
J Ravnik, M Diego, Y Gerasimenko, Y Vaskivskyi, I Vaskivskyi, T Mertelj, ...
Nature communications 12 (1), 2323 (2021)

"Quantum jamming transition to a correlated electron glass in 1T-TaS2"
YA Gerasimenko, I Vaskivskyi, M Litskevich, J Ravnik, J Vodeb, M Diego, ...
Nature materials 18, 1078 (2019)

"Fast electronic resistance switching involving hidden charge density wave states"
I Vaskivskyi, IA Mihailovic, S Brazovskii, J Gospodaric, T Mertelj, D Svetin, ...
Nature communications 7, 11442 (2016)

"Controlling the metal-to-insulator relaxation of the metastable hidden quantum state in 1T-TaS2"
I Vaskivskyi, J Gospodaric, S Brazovskii, D Svetin, P Sutar, E Goreshnik, ...
Science advances 1, e1500168 (2015)

"Ultrafast switching to a stable hidden quantum state in an electronic crystal"
L Stojchevska, I Vaskivskyi, T Mertelj, P Kusar, D Svetin, S Brazovskii, ...
Science 344, 177 (2014)

Professor Dr. Gheorghe L. Pascut
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Reason for invitation:

Gheorghe Lucian Pascut is a professor and a scientist working at the boundary between theory and experiment, with interests mostly in correlated materials. Pascut has spent the first half of his career so far working with X-ray and neutron scattering techniques and the second half with the state-of-the-art theoretical methods for correlated materials, applying embedded dynamical mean field theory (eDMFT) to understand real materials. Combining his experimental and theoretical expertise, he showed over the last decade that eDMFT methods can be used to explain and model experimental data quantitatively. In addition, he has also shown that starting from approximate models for the crystal structure, eDMFT has predictive powers for the electronic structural interply in correlated materials.

Recent few important/digested publications:

Combining his experimental and theoretical expertise, Pascut has proposed recently that resonant X-ray scattering experiments could be used as hints to find hidden states of matter with site or orbital selectivity ("Role of orbital selectivity on crystal structures and electronic states in $BiMnO_3$ and $LaMnO_3$ perovskites", Phys. Rev. B 107, 045147 (2023)). Their results show the existence of novel electronic states characterized by the coexistence of insulating, semi-metallic, and metallic orbitals. By self-consistent

determination of both the electronic state and the corresponding crystal structure, they show that the temperature evolution of these phases can be quantitatively explained from first principles, thus demonstrating the predictive power of the theoretical method for both the structural and the electronic properties.
In addition, based on his work over the last few years, he is proposing a different view/interpretation of what is called in the community “charge order/disproportionation” (“Mott Transition and Magnetism in Rare Earth Nickelates and its Fingerprint on the X-ray Scattering”, Scientific Reports 7, 10375 (2017)). The resonant elastic X-ray response at the K-edge, which was argued to be a probe of the charge order, is theoretically modelled within the Dynamical Mean Field Theory, including the core-hole interaction. They show that the line-shape of the measured resonant elastic X-ray response can be explained with the “site-selective” Mott scenario without real charge order on Ni sites.

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Reason for invitation:
Mazhar Ali is an Associate Professor in the Department of Quantum Nanoscience of the Faculty of Applied Sciences at TU Delft (Delft University of Technology) and is also part of the Kavli Institute of Nanoscience at Delft (KIND). He did his Bachelor’s degrees in Physics and Chemistry at UC Berkeley, his PhD in Chemistry and Materials at Princeton and his post-doc at IBM-Almaden before winning the Alexander von Humboldt Sofia Kovalevskaya award and becoming group leader at the Max Planck Institute for Microstructure Physics in Germany and then moving to TU Delft. He also serves as Chief Scientific Officer of Material Mind Inc., a materials intelligence start-up company. Ali's research group at TU Delft focuses on the 3Q's: Quantum Materials, Quantum Properties, and Quantum Devices, fabricating and exploring magnetic and electronic properties for both fundamental physics and next-gen technological applications.
Recent few important/digested publications:
Recently his group has focused on Kagome materials at the intersection of topology, frustration, and strongly correlation, with resulting highly impactful results like: discovery of the Josephson Diode effect (DOI: 10.1038/s41586-022-04504-8) using a strongly correlated 2D Kagome insulator as the tunnel barrier in a Josephson Junction, a giant anomalous Hall effect in a strongly correlated 2D topological Kagome semimetal (DOI: 10.1126/sciadv.abb6003), as well as meta magnetism in highly frustrated Kagome metals (DOI: 10.1021/acs.inorgchem.3c02172).