Condensed Matter Physics in the City 2021 – Abstract Booklet

Please find below the conference abstract with speakers in alphabetical order.

Manuel Brando: Electronuclear Quantum Criticality

I will present a rare example of electronuclear quantum criticality in a metal. The compound $YbCu_{4.6}Au_{0.4}$ is located at an unconventional quantum critical point (QCP). In this material the relevant Kondo and RKKY exchange interactions are very weak, of the order of 1 K. Furthermore, there is a strong competition between antiferromagnetic and ferromagnetic correlations, possibly due to geometrical frustration within the fcc Yb sublattice. This causes strong spin fluctuations which prevent the system to order magnetically. Because of the very low Kondo temperature the Yb^{3+} 4f-electrons couple weakly with the conduction electrons allowing the coupling to the nuclear moments of the ^{171}Yb and ^{173}Yb isotopes to become important. Thus, the quantum critical fluctuations observed at the QCP derive not from purely electronic states but from entangled electronuclear states. This is evidenced in the anomalous temperature and field dependence of the specific heat at low temperatures.

Paul Canfield 1,2: Synthesis as the heart of New Materials Physics

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Humanity needs to find the materials that will ease its growing needs for reliable, renewable, clean, energy and/or will allow for greater insight into the mysteries of collective and, in some cases, emergent states. The design, discovery and growth of novel materials is heart of the research effort that will, hopefully address these needs. In this talk I will present a broad overview of New Materials Physics and describe how a practitioner can go from staring at the periodic table to deciding what ``the next growth will be''. I will present and discuss the three basic motivations for making a growth: wanting a specific compound; wanting a specific ground state; searching for known and unknown unknowns. Materials discussed will span superconductors, quasicrystals, heavy fermions, fragile magnets, topological electronic systems, local moment magnets and a few lost puppies. The goal of this talk is to inspire and entertain, any resemblance to persons living or dead is coincidental. This talk is based on parts of my recent review article, “New Materials Physics”.[1]

[1] P. C. Canfield, Rev. Prog. Phys. 83, 016501 (2020).

John Chalker: Many-body delocalisation as symmetry breaking

I will give an overview of recent work on minimal models for quantum chaos and many-body localisation. The models are Floquet quantum circuits for lattice spin systems, in which time evolution is generated by unitary gates that couple neighbouring sites. In particular, I will discuss the circumstances in which a version of the so-called diagonal approximation (originally developed for the semiclassical limit in low-dimensional chaotic systems) can be applied to these systems. Within this framework I will show that the many-body delocalisation transition can be seen as a form of symmetry breaking transition, having many of the features generally associated with conventional phase transitions in classical statistical mechanical models.

Joint work with Sam Garratt: arXiv:2008.01697 and arXiv:2012.11580

Claudio Chamon: Fracton Topological Order

A major goal of condensed matter physics is to understand and to classify all possible phases of matter; another one is to uncover phases outside contemporary paradigms. While these two goals are evidently contradictory, together they move the field forward. An example of a new class of systems whose complete understanding is still in progress is that of what is now commonly referred to as fractons in general, or more precisely, systems with fracton excitations. These systems have rich properties that can be studied from diverse perspectives, including topological order, quantum dynamics, elasticity, and fundamentals of quantum field theory.

In the first lecture we will introduce fracton systems from the lattice perspective, and concentrate on their quantum dynamics and topological order.

Weslei Fontana & Claudio Chamon: Fracton topological order in the continuum

In the second talk we will discuss how to obtain field theories for fracton lattice models. This is done by representing the lattice degrees of freedom with Dirac matrices, which are then related to continuum fields by means of a "bosonization" map. This procedure allows us to obtain effective theories which are of a Chern-Simons-like form. we will show that these Chern-Simons-like theories naturally encode the fractonic behavior of the excitations and that these theories can describe even type-II fracton phases.

Kaden Hazzard: Correlations and Universality of the SU(N) Fermi-Hubbard model in ultracold matter

The SU(*N*) Hubbard model generalizes the SU(2) Hubbard model to larger spins S>1/2 with a special interaction symmetry that enhances quantum fluctuations compared to typical large-spin models. It has been predicted to harbor a variety of exotic magnetic ground states, including valence bond solids and topological spin liquids.

Excitingly, this model has been shown to occur in ultracold matter for N experimentally controllable and as large as 10, with the SU(*N*) not a rough approximation, but accurate to 10^-9. However, just as for the *N*=2 Hubbard model, it has remained an outstanding challenge for cold atoms experiments to achieve temperatures low enough to observe phenomena such as superconductivity and magnetic order.

I will describe how enlarging SU(2) to SU(*N*) not only enriches the physics, but lowers the temperature and increases magnetic correlations, as recently observed by our experimental collaborators [1] in 1D, 2D, and 3D. Our calculations agree with the measurements in broad regimes. This allows thermometry, showing that the experiments in 1D have produced the coldest fermions ever achieved. The calculations also reveal surprising universality in the equations of state, pointing to simple underlying physics. Finally, I will describe important future directions for understanding longer range correlations and dynamics.

[1] S. Taie, E. Ibarra-García-Padilla, N. Nishizawa, Y. Takasu, Y. Kuno, H.-T. Wei, R. T. Scalettar, K. R. A. Hazzard, Y. Takahashi, arXiv:2010.07730

Aharon Kapitulnik: Experimental search for Chiral Superconductors

TBD.

Johnpierre Paglione: Exotic superconductivity in nearly ferromagnetic UTe2

Topological superconductivity has attracted great interest in condensed matter physics because of its potential applications in quantum computing. Spin-triplet superconductors are one promising class that can host the topological excitations of interest, but experimental realizations are few and far between. Here we report the discovery and properties of superconductivity in UTe2, a material closely related to known ferromagnetic superconductors such as UGe2, URhGe, and UCoGe, but lacking long-range magnetic order. Several experimentally measured properties feature telltale indications of an unconventional energy gap and a spin-triplet pairing state that is consistent with the presence of strong magnetic fluctuations due to an incipient quantum critical point. Furthermore, the superconductivity in UTe2 is remarkably robust to extremely high magnetic fields, showing re-entrant pairing up to at least 65 Tesla. I will review basic properties and our detailed investigations of the gap structure, relation to incipient magnetic order and Kondo coherence, as well as indications of an anomalous normal state fluid that suggest many surprises await for this exotic material.

Frank Pollmann (I): "Far-from-equilibrium dynamics of systems with conservation laws”

(Introductory Lecture)**:**

Recent years have seen a great deal of effort to understand quantum thermalization: the question of whether closed quantum systems, evolving under unitary dynamics, reach a state of thermal equilibrium. In my talk, I will discuss how the presence of different conservation laws affects the dynamics of thermalization. First, we investigate the dynamics of quantum entanglement in systems with conservation laws and uncover a qualitative difference between the behavior of the von Neumann entropy and higher Renyi entropies. We argue that the latter generically grow sub-ballistically in systems with diffusive transport. We provide strong evidence for this in both a U(1) symmetric random circuit model and in a paradigmatic non-integrable spin chain, where energy is the sole conserved quantity. Second, we show that systems conserving the dipole moment of an associated global charge exhibit a slow subdiffusive transport. Modelling the time evolution as cellular automata for specific cases of dipole conservation, we numerically find distinct anomalous exponents of the late time relaxation. We explain these findings by analytically constructing a general hydrodynamic model that results in a series of exponents depending on the number of conserved moments, yielding an accurate description of the scaling form of charge correlation functions.

Frank Pollmann (II): "Exploring Topological Order on Quantum Processors”

Universal quantum computers are potentially an ideal setting for simulating emergent quantum many-body phenomena that are out of reach for classical computers. Here I discuss our recent work in which we prepare the ground state of the toric code Hamiltonian using an efficient quantum circuit on a superconducting quantum processor. We measure a topological entanglement entropy near the expected value of ln(2), and simulate anyon interferometry to extract the braiding statistics of the emergent excitations.

Adam Smith:

Models whose ground states can be written as an exact matrix product state (MPS) provide valuable insights into phases of matter.

While MPS-solvable models are typically studied as isolated points in a phase diagram, they can belong to a connected network of MPS-solvable models, which we call the MPS skeleton. As a case study where we can completely unearth this skeleton, we focus on the one-dimensional BDI class---non-interacting spinless fermions with time-reversal symmetry. We show that one can read off from the Hamiltonian whether its ground state is an MPS and provide an explicit construction of the ground state MPS, its bond dimension growing exponentially with the range of the Hamiltonian. This complete characterization of the MPS skeleton in parameter space has three significant consequences: (i) any two topologically distinct phases in this class admit a path of MPS-solvable models between them, including the phase transition which obeys an area law for its entanglement entropy; (ii) we illustrate that the subset of MPS-solvable models is dense in this class by constructing a sequence of MPS-solvable models which converge to the Kitaev chain (equivalently, the quantum Ising chain in a transverse field); (iii) a subset of these MPS states can be particularly efficiently processed on a noisy intermediate-scale quantum computer, which we demonstrate on an IBM quantum computer.