11^{th} Ts-Lj-Zg meeting in stat. phys. & cond. matt.

Faculty of mathematics and physics, University of Ljubljana

January 31, 2024

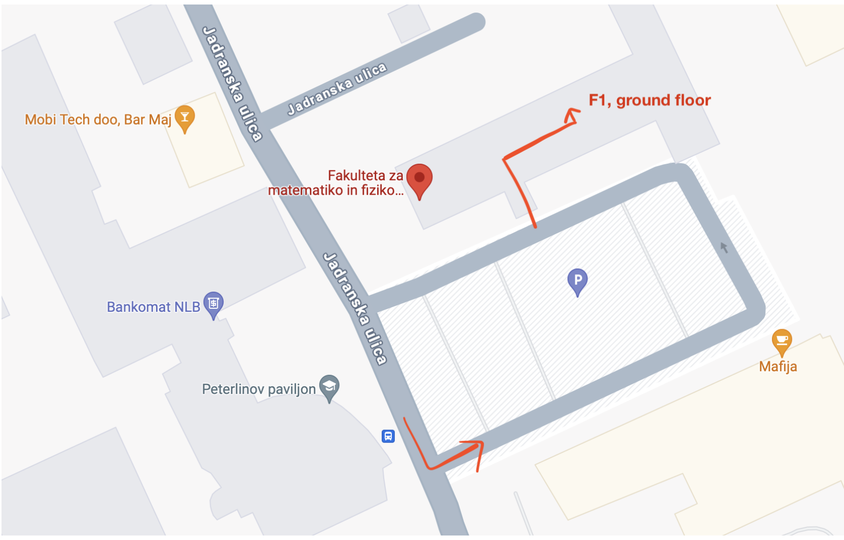
Time slot	Speaker
10:00–10:30	Cheryne Dea Jonay (FMF) *Aspects of entanglement, chaos, and hydro in quantum many-body systems*
10:30–11:00	Federico Rottoli (SISSA) *Negativity Hamiltonian from pure to mixed states*
11:00–11:30	Coffee break
11:30–12:00	Gianpaolo Torre (IRB) *Topologically Frustrated ANNNI Chain*
12:00–12:30	Jacopo Niedda (ICTP) *Glass and pseudo-localization transitions in random lasers*
12:30–14:00	Discussions & lunch break
14:00–14:30	Andrea Solfanelli (SISSA) *Exploring discrete floquet time crystals in long-range interacting quantum systems*
14:30–15:00	Iris Ulčakar (IJS) *Iterative construction of conserved quantities in dissipative nearly integrable systems*
15:00–15:30	Zeno Bacciconi (ICTP) *Cavity control of the fractional quantum Hall effect*
15:30–	Coffee & discussions

FMF	=	Faculty of Mathematics and Physics (Ljubljana)
IJS	=	Jožef Stefan Institute (Ljubljana)
IRB	=	Ruđer Bošković Institute (Zagreb)
SISSA	=	International School for Advanced Studies (Trieste)
ICTP	=	International Centre for Theoretical Physics (Trieste)

FMF local organizer: Lenart Zadnik

Location

The meeting will take place in the **auditorium F1**, on the ground floor of the Physics department (Jadranska 19).



Session 1, 10:00

Cheryne Dea Jonay (FMF): *Aspects of entanglement, chaos, and hydro in quantum many-body systems*

In this short talk, I will introduce three recent works addressing quantum thermalization, chaos, and hydrodynamics in 1-d spin chains. The first work addresses the microscopic process driving thermalization in a generic class of quantum circuits. The main result is that there is a competition between emergent modes, resulting in multi-stage thermalization of observables and entanglement. The second introduces a framework to quantify chaos by comparing eigenstate entanglement entropy distributions to random matrix theory, enabling a more fine-grained metric than the usual spectral diagnostics. In the third part, I will introduce a recent idea to use insights from holography to study the hydrodynamics of chaotic boundary models. The bulk theory simplifies the identification of hydrodynamic variables through emergent dynamics of a simple (local and unitary) quantum circuit.

Federico Rottoli (SISSA): *Negativity Hamiltonian from pure to mixed states*

The entanglement Hamiltonian, defined as the logarithm of the reduced density matrix, provides the most complete characterisation of bipartite entanglement in pure states. In analogy with this quantity, recently the Negativity Hamiltonian has been introduced as a non-Hermitian operator which characterises entanglement in mixed states. We review the concept of Negativity Hamiltonian and we present analytical results in both the ground and in a thermal state of the massless Dirac fermion field theory in 1+1 dimensions, highlighting the main features and the differences with respect to the Entanglement Hamiltonian. We finally compute numerically the Negativity Hamiltonian in a critical lattice model, comparing the lattice results with the asymptotic QFT prediction. A proper comparison requires a non-trivial continuum limit which takes into account couplings between fermions at all distances.

Session 2, 11:30

Gianpaolo Torre (IRB): *Topologically Frustrated ANNNI Chain*

Frustration originates from the impossibility of minimizing simultaneously all the local energy constraints. In 1D spin chains with nearest-neighbor interaction, frustration can be introduced by applying a ring geometry with appropriate boundary conditions. When paired with antiferromagnetic interactions, this frustration has been proven to modify several system properties, such as the closing of the energy gap in traditionally gapped phases, the emergence of long-range correlations, and the vanishing (or spatial dependence) of the order parameters. In this talk, we study the interplay between the boundary-condition induced topological frustration and that of local nature due to the presence of competing next-to-nearest neighbor interactions. We consider the 1D ANNNI model since it allows us to explore both kinds of frustrations by tuning the couplings and the boundary conditions. In particular, we focus on the degree of entanglement within the system as measured by the entanglement entropy (EE). In the antiphase, we find that topological effects are present with the EE violating the area law, providing a non-diverging extensive contribution that depends on the subsystem length. Furthermore, in the thermodynamic limit, the local and topological contributions are decoupled, and the EE can be expressed as the sum of the two terms. In contrast to the systems in which only the Topological frustration is present, this phenomenology cannot be interpreted in terms of a delocalized excitation within the system.

Jacopo Niedda (ICTP): *Glass and pseudo-localization transitions in random lasers*

Optical waves in active disordered media display the typical phenomenology of complex systems. The multiple scattering of light with randomly placed scatterers inside a material confines the electromagnetic field and entails the existence of well-defined cavity modes with long lifetimes competing for amplification. The presence of modes in random lasers can be revealed from the highly structured spectra measured in experiments. If one takes several spectral shots from the same piece of material, the position of the intensity peaks changes from shot to shot, meaning that there is no specific frequency which is preferred in the lasing phenomenon, but depending on the initial state, with the disorder kept fixed, the modes gaining the highest intensity change every time. In order to explain this behaviour, a statistical mechanics model derived from spin-glass theory has been developed, where the light modes are described as non-linearly interacting phasors on the so-called mode-locked diluted graph [1]. In this talk we present recent results from numerical simulations of the mode-locked glassy random laser. The presence of a phenomenology compatible with a glass transition when tuning the optical power of the system above a threshold value is put in evidence from the divergence of the specific heat and a non-trivial structure of the Parisi overlap distribution function. By means of a refined finite-size scaling analysis of the critical region, the transition is assessed to be compatible with a mean-field universality class [2]. A pseudo-localization transition to a phase where the intensity of light is neither properly localized on a single mode nor equiparted among all modes is revealed from the measurement of the inverse participation ratio and of the spectral entropy [3]. The two transitions occur at the same temperature as different manifestations of the same underlying phenomenon, the breaking of ergodicity.

[1] F. Antenucci, C. Conti, A. Crisanti, L. Leuzzi, Phys. Rev. Lett. 114, 043901 (2015).
[2] J. Niedda, G. Gradenigo, L. Leuzzi, G. Parisi, SciPost Phys. 14, 144 (2023).
[3] J. Niedda, L. Leuzzi, G. Gradenigo, J. Stat. Mech. 053302 (2023).

Session 3, 14:00

Andrea Solfanelli (SISSA): *Exploring discrete floquet time crystals in long-range interacting quantum systems: from theoretical foundations to digital duantum simulations*

Discrete Floquet time crystals (DFTCs) are unique nonequilibrium many-body phases characterized by the breaking of the discrete time translation symmetry of the Floquet driving, and by an order parameter displaying persistent oscillations with a period that is an integer multiple of the driving period. The talk explores their potential generation in clean systems, with a focus on long-range interacting models. In the first part, I will introduce a novel order parameter to detect discrete time crystalline phases in quantum systems with strong long-range interactions. This tool is applied to characterize the out-of-equilibrium phase diagram of the long-range kicked Ising model, revealing a rich landscape with self-similar fractal boundaries. The second part presents outcomes from a digital quantum simulation effort, addressing qubit connectivity limitations in noisy intermediate-scale quantum devices. By exploiting the universality of native quantum processor gates, I will show how to implement couplings among physically disconnected qubits. Finally, I will present the results from a quantum simulation on IBM superconducting quantum processors benchmarking the prethermal stabilization of discrete Floquet time crystalline response with increasing interaction range.

Iris Ulčakar (IJS): *Iterative construction of conserved quantities in dissipative nearly integrable systems*

Integrable systems offer rare examples of solvable many-body problems in the quantum world, but due to their fine-tuned structure, the effects of integrability in nature are observed only transiently. One way to overcome this limitation is to weakly couple nearly integrable systems to baths and driving: these will stabilize integrable effects up to arbitrary time and encode them in the stationary state approximated by a generalized Gibbs ensemble. However, the description of such driven dissipative nearly integrable models is challenging and no exact analytical methods have been proposed so far. In this talk, I will present an iterative scheme in which integrability breaking perturbations (baths) determine the conserved quantities that play the leading role in a truncated generalized Gibbs ensemble description. I will first benchmark our approach on the paradigmatic transverse field Ising and Heisenberg models coupled to Lindblad baths. For the former, I will show how to evaluate the scheme for thermodynamically large systems and obtain a non-thermal steady state despite infinitesimal couplings to baths.

[1] I. Ulčakar and Z. Lenarčič, arXiv:2310.03809 (2023).

Zeno Bacciconi (ICTP): *Cavity control of the fractional quantum Hall effect*

In recent years the possibility of controlling properties of quantum many body systems by means of cavity embedding has attracted a lot of attention. Among these efforts, recent experimental results have shown that vacuum fluctuations of an extended cavity mode are able to affect transport properties in the Integer Quantum Hall regime. From a fundatmental point of view, the effect of strongly coupled extended cavity modes challenges the understanding of resilience to local perturbations of topological states of matter. In this talk I will present results [1] concerning the coupling of a realistic cavity set-up to a Fractional Quantum Hall state. We find that for a finite regime of coupling strengths the topological order of the state is stable. Only at strong coupling the quantum fluctuations of the cavity mode drive a transition to a charge density wave state.

[1] Z. Bacciconi, T. Chanda, H. Xavier, M. Dalmonte, *in preparation*.