8th Trieste-Ljubljana-Zagreb Meeting

Statistical Physics and Condensed Matter Theory

ICTP (Trieste), December 6, 2022

Time slot	Speaker
09:30–10:00	Welcome coffee & opening remarks
10:00–10:30	Filiberto Ares (SISSA) *Entanglement asymmetry as a probe of symmetry breaking*
10:30–11:00	Žiga Krajnik (FMF) *Anomalous fluctuations and dynamical universality*
11:00–11:30	Jovan Odavić (IRB) *Complexity of frustration*
11:30–14:30	Discussions & lunch break
14:30–15:00	Poetri Tarabunga (ICTP) *Topological phases of matter with Rydberg atom arrays*
15:00–15:30	Carlo Vanoni (SISSA) *Interface dynamics in the 2D quantum Ising model*
15:30–16:00	Coffee break
16:00–16:30	Jan Šuntajs (IJS) *Localization challenges quantum chaos in finite two-dimensional Anderson model*
16:30–17:00	Anton Kutlin (ICTP) *Anatomy of the eigenstates distribution: a quest for a genuine multifractality*
17:00–	Closing remarks & 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)

Session 1, 10:00

Filiberto Ares (SISSA): *Entanglement asymmetry as a probe of symmetry breaking*

Symmetry and symmetry breaking are two pillars of modern quantum physics. However, quantifying how much a symmetry is broken is an issue that has received little attention. In extended quantum systems, this problem is intrinsically bound to the subsystem of interest. In this talk, we will borrow methods from the theory of entanglement in many-body quantum systems to introduce a subsystem measure of symmetry breaking that we dub entanglement asymmetry. As a prototypical illustration, we will study the entanglement asymmetry in a quantum quench of a spin chain in which an initially broken global $U(1)$ symmetry is restored dynamically. We will find, expectedly, that larger is the subsystem, slower is the restoration, but also the counterintuitive result that more the symmetry is initially broken, faster it is restored, a sort of quantum Mpemba effect.

Žiga Krajnik (FMF): *Anomalous fluctuations and dynamical universality*

Conventional classification of dynamical phenomena is based on universal hydrodynamic relaxation characterized by algebraic dynamical exponents and asymptotic scaling of the dynamical structure factor. We argue that dynamical universality classes can instead be naturally distinguished based on their full-counting statistics. As an example we consider a general class of one-dimensional single-file systems of interacting hardcore charged particles. Dynamical constraints give rise to universal anomalous statistics of cumulative charge currents, manifested both on the timescale characteristic of typical fluctuations and also in the rate function describing rare events. Typical fluctuations in equilibrium are governed by a universal distribution that markedly deviates from the expected Gaussian statistics, whereas large fluctuations are described by a large-deviation rate function featuring an exceptional triple critical point. Far from equilibrium, competition between dynamical phases leads to dynamical phase transitions of first and second order. We point out some connections with charge fluctuations in integrable spin chains.

Jovan Odavić (IRB): *Complexity of frustration*

In this talk, I will present recent results on the topic of integrable topologically frustrated quantum spin chains. In particular, I will discuss entanglement properties of frustrated Ising chains with assumed frustrated boundary conditions that imply periodic boundary conditions, an odd number of spins, and antiferromagnetic coupling. The topologically frustrated ground state is a unique example of a state associated with a local and nearest-neighbor coupling Hamiltonian that violates the area-law scaling of entanglement with the subsystem size. Frustrated boundary conditions induce an excess of long-range entanglement that can be analytically described in the thermodynamic limit using the single-particle interpretation. Using an entanglement cooling (disentangling) algorithm, represented by a particular stochastic quantum circuit, we show that the frustration-induced entanglement is robust against the application of local gates. In this process, we additionally demonstrate, how with different choices of local gates the quantum circuit can induce a transition in the entanglement spectrum from the uncorrelated Poissonian distributed eigenvalue spacings to the correlated Wigner-Dyson distribution. Moreover, we advance the characterization of complexity in quantum many-body systems by examining W -state, a well-known state within the quantum information community. Such a state admits an amount of non-stabilizerness or "magic" (measured as the Stabilizer Rényi Entropy – SRE) that grows logarithmic with the number of qubits/spins. We show that topologically frustrated ground states have a value of SRE that is the sum of that of the W-state plus an extensive local contribution. Our work reveals that W-states/frustrated ground states display a non-local degree of complexity that can be harvested as a quantum resource and has no counterpart in GHZ states/non-frustrated systems.

[1] J. Odavić *et al.*, arXiv:2209.10541.
[2] J. Odavić *et al.*, arXiv:2210.13495.

Session 2, 14:30

Poetri Tarabunga (ICTP): *Topological phases of matter with Rydberg atom arrays*

Over recent years, Rydberg atom arrays has become one of the versatile platforms for the realization of exotic quantum many-body phases, such as topological phases. In this talk, I will discuss recent theoretical proposals to realize two different types of topological phases, namely, (i) $\mathbb{Z}_2$ quantum spin liquids (QSLs) and (ii) (chiral) bosonic Integer Quantum Hall (BIQH) phase in Rydberg atom arrays. In the first case, I will discuss how the strong van der Waals interactions between the Rydberg states can lead to emergent $\mathbb{Z}_2$ gauge symmetries, which is crucial for stabilizing $\mathbb{Z}_2$ QSL. On the other hand, the BIQH phase is predicted in a different setting, where spin-orbit coupling leads to density-dependent hopping of Rydberg states. In this case, the origin of the BIQH phase can be argued to be the Chern-Simons gauge field generated by the density-dependence of the hopping.

Carlo Vanoni (SISSA): *Interface dynamics in the 2D quantum Ising model*

I will show how the melting of a smooth interface in the 2D quantum Ising model with transverse and longitudinal fields shows signs of localization. This is done by means of a "holographic" mapping to a 1D integrable model of fermions in the large ferromagnetic coupling J limit and after the systematic introduction of $1/J$ corrections. I will also discuss the scenario in the presence of a random external field.

Session 3, 16:00

Jan Šuntajs (IJS): *Localization challenges quantum chaos in finite two-dimensional Anderson model*

It is believed that the two-dimensional (2D) Anderson model exhibits localization for any nonzero disorder in the thermodynamic limit and it is also well known that the finite-size effects are considerable in the weak disorder limit. Here, we numerically study the quantum-chaos to localization transition in finite 2D Anderson models, using standard indicators used in the modern literature, such as the level spacing ratio, spectral form factor, variances of observable matrix elements, participation entropy and the eigenstate entanglement entropy. We show that many features of these indicators may indicate emergence of single-particle quantum chaos at weak disorder. However, we argue that a careful numerical analysis is consistent with the oneparametric scaling theory and predicts the breakdown of quantum chaos at any nonzero disorder value in the thermodynamic limit. Among the hallmarks of this breakdown are the universal behavior of the spectral form factor at weak disorder and the universal scaling of various indicators as a function of the parameter $u = (W \log V)^{-1}$ where W is the disorder strength and V is the number of lattice sites.

[1] J. Šuntajs, T. Prosen and L. Vidmar, *in preparation*.

Anton Kutlin (ICTP): *Anatomy of the eigenstates distribution: a quest for a genuine multifractality*

Due to a series of recent works [1-4], an interest in multifractal states has risen as they are believed to be present in the MBL phase. Inspired by the success of the Rosenzweig-Porter (RP) model with normally distributed transition amplitudes, a similar ensemble but with the fat-tailed distributed amplitudes was proposed [5-9], with claims that it hosts the desired multifractal phase. In the present work, we develop a general (graphical) approach allowing a self-consistent analytical calculation of the spectrum of eigenstate's fractal dimensions (SFD) for various RP models and investigate what features of the RP Hamiltonians can be responsible for the multifractal phase emergence. We conclude that, for a broad set of models, the only feature contributing to a genuine multifractality is the on-site energies distribution, meaning that no random matrix model with uniformish diagonal and uncorrelated off-diagonal disorder with the convex distribution of the matrix elements' logarithm can host a genuine multifractal phase and hence model a true MBL.

[1] J. Z. Imbrie, V. Ros, and A. Scardicchio, Ann. Phys. **529**, 7, 1600278 (2017).
[2] G. De Tomasi *et al.*, Phys. Rev. B **104**, 024202 (2021).
[3] A. Morningstar *et al.*, Phys. Rev. B **105**, 174205 (2022).
[4] N. Macé *et al.*, Phys. Rev. Lett., **123**,180601 (2019).
[5] C. Monthus, J. Phys. A: Math. & Theor. **50**, 29, 295101, (2017).
[6] V. Kravtsov *et al.*, arXiv:2002.02979 (2020).
[7] I. M. Khaymovich *et al.*, Phys. Rev. Research **2**, 043346 (2020).
[8] G. Biroli and M. Tarzia, Phys. Rev. B, **103**, 104205 (2021).
[9] I. M. Khaymovich and V. E. Kravtsov, SciPost Phys. **11**, 045 (2021).

List of participants

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