The Dynamics of Quantum Information (DYNQ18)
Final Report on KITP Program, August 6 – November 2, 2018

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Overview. The phase structure of driven quantum systems, the random growth of interfaces, the gravity duals of strongly coupled quantum field theories: on the face of it, these are completely unrelated phenomena operating on vastly distinct length and time scales, accessed via tools as diverse as statistical mechanics, stochastic nonequilibrium dynamics, and general relativity. Yet, these are just three of the many fundamental problems of theoretical physics that emerge as central to the dynamics of information and entanglement in quantum systems. Quantum information has already revolutionized our understanding of the equilibrium properties of strongly-interacting systems, by inspiring numerical techniques that enable the efficient computation of their ground states and low-lying excitations. The next generation of these methods promise to do the same for our understanding of the dynamics of quantum systems. Yet, traditional formulations of many-body dynamics usually ignore this quantum information perspective, eschewing it in favor of addressing more conventional questions of dissipation, dephasing, and transport.

The DYNQ18 program focused on three inter-connected themes that have witnessed dramatic recent progress:

isolated systems out of equilibrium*:* the advent of techniques to cool and trap large collections of atoms, molecules and ions has resulted in renewed attention to the study of the dynamics of isolated quantum systems. Several recent theoretical and experimental advances in this field have hinged on the recognition that some isolated systems evade thermalization and are instead *many-body localized;* the resulting nonequilibrium behaviors can include those forbidden by arguments from equilibrium statistical physics. A localized isolated system can be periodically driven without heating it up, leading to robust absolutely stable "Floquet" phases of matter such as "time crystals", that generically lack conserved quantities. A unified perspective of such nonequilibrium phases is afforded by considering their entanglement properties, and bounds on their ability to spread quantum information. Transitions between different nonequilibrium phases, or the establishment of thermal equilibrium when many-body localization breaks down, are also most naturally viewed using a quantum information-theoretic lens. Spurred by this, there has also been much recent interest in developing numerical techniques that can efficiently simulate the dynamics of highly excited states. The questions of nonequilibrium phenomena have thus rapidly emerged as among the most promising testing grounds for the ideas of quantum information.

tensor networks and dynamics: the dramatic success of the density matrix renormalization group in describing one dimensional many body systems is now understood to stem from its efficient representation of quantum states in terms of "tensor networks", that accurately approximate quantum ground states of gapped systems. Besides a host of technical improvements in describing ground states with tensor networks, an efficient description of quantum dynamics remains elusive except in a few special cases. Deeper understanding of the intrinsic dynamical properties of tensor networks — formulated in terms of the spread of entanglement in tensor network states — promises to reveal new directions in the simulation of quantum dynamics. Recent results have leveraged the entanglement properties of random tensor networks to construct toy models of the gauge-gravity duality, while other work has uncovered surprising connections between simplified models of entanglement growth in such states and the description of the dynamics of random interfaces via the celebrated Kardar-Parisi-Zhang equation. Other ideas, such as reframing the path-integral formulation of quantum mechanics in terms of tensor networks, may also become increasingly important tools in studying dynamical issues. A common thread that runs through these developments is that *classical* statistical mechanics and stochastic dynamics can be fruitfully used to achieve insight into *quantum* problems — but in manner rather distinct from the standard quantum-to-classical mappings familiar from equilibrium problems.

black holes, holography and tensor networks: starting with the work of Bekenstein and Hawking, it has become clear that classical information and entropy play important roles in the physics of black holes. Surprisingly, the more recent "holographic" formulation of gravity in universes with negative cosmological constant has made it clear that quantum information is also crucial to the physics of black holes. For example, quantum entanglement appears necessary to knit together spacetime out of nongravitational degrees of freedom, and a particular kind of chaotic "scrambling" dynamics of quantum information emerges from the physics of black hole horizons. These developments raise a number of exciting possibilities related to the dynamics of quantum information including new fundamental bounds on quantum dynamics, new "gravity inspired" tensor network methods to describe quantum dynamics, and new information-theoretic signatures of quantum thermalization in isolated systems. Such questions are particularly aligned with the other core topics given that the black hole information problem is closely related to the dynamics of isolated quantum systems and given that tensor network methods have helped elucidate the emerging connections between black holes and quantum information.

The DYNQ18 program brought to KITP leading experts in each of these focus areas, as well as those from the closely-related communities of classical nonequilibrium statistical physics and quantum integrability, for a several-week focused workshop. Since the parallel *Chaos & Order* program (CHORD18) on black holes, chaos and Sachdev-Ye-Kitaev model ran concurrently with DYNQ18, we coordinated with its organizers to slant the focus of the third focus area of DYNQ18 and align it closer to questions on tensor networks. The black-hole/holography component was amply covered by the parallel program. This change in emphasis also aligned well with very recent developments in the field of non-equilibrium dynamics: the emergence of "generalized hydrodynamics" as a new theme of research meant that several participants were interested in extending DYNQ18 to focus on these, and the shift in emphasis was smoothly achieved in this fashion.

Organization. The typical weekly schedule of the program was as follows. Typical weeks had two one-hour scientific talks, on Tuesday and Thursday afternoons. Friday was devoted to a longer/more open-ended talk, often framed as a discussion but usually with 30-40 minutes of prepared material from a discussion leader. These included discussions on time crystals and Floquet phases (C. von Keyserlingk, D. Else), random unitary dynamics (A. Nahum), numerical techniques for dynamics (F. Pollmann, S. White), quantum scars (W. Ho, Z. Papic. C. Turner & M. Serbyn). A broader panel-style discussion on "The outlook for quantum dynamics" guided by V. Khemani, J. Bardarson, A. Polkovnikov, R. Vasseur, and R. Nandkishore closed off the program.

On weeks when an "Experimentalist of the Week" was in residence at KITP, their talk was usually allocated to Wednesdays. Experimentalists included R. Islam (ion traps), D. Weiss (quantum dynamics of one-dimensional systems & quantum computing), N. Navon (quantum gases), Z. Ovadyahu (electron glasses) and A. Kollar (circuit QED).

An innovation of this KITP workshop was to organize a series of longer pedagogical talks, to facilitate better cross-communication between the diverse communities represented. This also served to allow a higher level of discussion: speakers further on in the program were able to dispense with extensive background material and focus on new results, while participants who arrived later in the program could quickly orient themselves with the state of the art by viewing the video of the pedagogical sessions. Key sessions included those on Random Circuits (by J. Chalker), the Kardar-Parisi-Zhang Equation (by M. Kardar), on constrained dynamics (J. Garrahan), on integrability (by F. Essler), on quantum hydrodynamics (by J.E. Moore).

Outcomes. The activity reports suggest that the program substantially achieved its goal of fostering dialog between the diverse research communities that it brought together. Several new and significant collaborations were seeded at the workshop, and many existing collaborative projects were advanced or brought to fruition during DYNQ18. Given that the workshop was held August 6 – November 2, concluding just over 2 months prior to the writing this report, many of these are ongoing, but a partial list, with preprints where already available, follows. Note that many participants also benefited from discussions with people in the broader KITP/Physics/Station Q community on topics outside those directly linked to DYNQ18; for space reasons we have omitted these from our list. We have also generally focused on concrete collaborations; there were many more informal discussions during the program that have significantly impacted many participants view of the field.

1. Many-Body Localization Phase Transition: One significant area of progress was on the theory of the MBL transition. P. Dumitrescu, S.A. Parameswaran, A. Goremykina, M. Serbyn and R. Vasseur developed a new picture of the transition as being controlled by an underlying Kosterlitz-Thouless RG flow that governs "quantum avalanches", and matches on to a previously. This benefited from discussions with other participants (W. De Roeck, F. Huveneers) who developed the avalanche picture, and coincided with the publication of microscopic numerics that appear consistent with this scenario (by J. Bardarson). Further papers are expected from this collaborative work. [arXiv:1811.03103]

2. Multiscale entanglement at MBL transitions: Jens Bardarson completed a work on the structure of entanglement near the MBL transition. This was closely related to the work (see #1 above) on the MBLT by other DYNQ18 participants. [arXiv:1811.01925]

3. Emergence of Diffusion from Hydrodynamics: S. Gopalakrishnan, V. Khemani, and R. Vasseur (and D. Huse, who could not attend DYNQ18) developed an elegant explanation for the emergence of diffusion in integrable systems using a "kinetic theory" approach that marries the techniques of thermodynamic Bethe ansatz to the techniques of Boltzmann transport. This also benefited from conversations with T. Prosen. [arXiv: 1809.02126]

4. Spin Transport in the XXZ Chain: M. Znidaric worked on superdiffusive spin transport at the isotropic point, in a collaboration with his PhD student Marko Ljubotina. Separately V. Alba and S. Gopalakrishnan held extensive discussions on dynamics in the gapped phase and are preparing a draft on this topic.

5. Random-Matrix Ensembles for Chaotic dynamics: A. Lamacraft and S. Gopalakrishnan began a project on understanding the random-matrix ensembles that describe a state during its time-evolution under chaotic dynamics. This is conceptually related to the work on random matrix properties on entanglement spectrum dynamics but technically distinct.

6. Matrix Elements beyond ETH: J. T. Chalker, A. De Luca, and A. Chan (not at DYNQ18) developed a theory of matrix element correlations in chaotic many- body systems beyond those captured by the eigenstate thermalisation hypothesis. [arXiv:1810.11014]

7. Tree tensor networks for critical MBL phases: Sid Parameswaran and Romain Vasseur worked closely with Brayden Ware (affiliate) on developing tree tensor network techniques to tackle MBL critical points and phases. This work in on-going, and benefited from discussions with Bryan Clark.

8. Disordered Gauge theories: Sid Parameswaran and Romain Vasseur also made some progress on a project to study deconfinement transitions in disordered gauge theories in two dimensions with Snir Gazit and Byungmin Kang (not DYNQ18 participant). This will lead to a publication in the near future.

9. Conserved quantities and Entanglement dynamics: Vedika Khemani, Romain Vasseur, and Sarang Gopalakrishnan had many discussions (together with David Huse, who wasn't able to attend the workshop) on the role of conserved quantities and fluctuations on entanglement dynamics. This work is on-going.

10. Prethermalization and Thermalization in Isolated Quantum Systems: Wojciech De Roeck, Krishnanand Mallayya (affiliate), and Marcos Rigol developed and thoroughly tested numerically a theoretical framework to understand weakly perturbed (possibly nonintegrable) reference dynamics, in which the perturbation breaks at least one conservation law. They showed that thermalization in the system proceeds via intermediate (generalized) equilibrium states of the reference dynamics, and derived and tested the corresponding autonomous equation. [arXiv:1810.12320]

11. Statistical mechanics model for projective measurements-induced transitions: Yi-Zhuang You and Romain Vasseur started a collaboration with Andreas Ludwig and Chao-Ming Jian (both local) on entanglement transitions driven by projective measurements. This project should lead to a paper soon.

12. Revivals in 1d Bose gas: Kartiek Agrawal and Romain Vasseur had several discussions about revivals in 1d Bose gas, and how they could be studied using hydrodynamics.

13. Holographic Renyi Entropy: X. Dong completed a study of Renyi entropies in holographic models but at large entropy densities, and showed that Renyi entropies of subregions can be used to distinguish when the entire system is in a microcanonical ensemble from when it is in a canonical ensemble, at least in theories holographically dual to gravity. This also led to ongoing collaborations with T. Grover. [arXiv: 1811.04081]

14. Entanglement Entropy of Excited Eigenstates of Integrable Models: Marcos Rigol and Lev Vidmar, together with Eugenio Bianchi and Lucas Hackl (not DYNQ18 participants),

completed a project on the universal properties of the leading (volume law) and first subleading terms of the average bipartite entanglement entropy of eigenstates of the quantum Ising model in one dimension. [Phys. Rev. Lett. **121**, 220602 (2018)].

15. Thermal Transport in Spin Liquids and 1D Lattice models: W. Brenig and collaborators completed a paper on heat transport in Kitaev spin liquids, and continue to pursue further studies in this direction. M. Znidaric and F. Heidrich-Meisner also worked on related topics with collaborators, and both benefited from discussions at DYNQ18; they also are co-authoring a review to be submitted to Rev. Mod, Phys. on this topic. T. Prosen, who attended the conference, was also involved in some of this work. These projects, while not directly linked to the quantum information aspects of the program, directly bear on experimental questions of transport that motivate the more fundamental questions of chaos and quantum dynamics. [arXiv:1810.04674, arXiv:1809.08429]

16. Floquet Anderson Insulators: J.T. Chalker, V. Khemani, S.L. Sondhi and D.T. Liu (not at DYNQ18) completed a paper on the response of periodically driven Anderson insulators in different dynamical regimes, involving both pre-existing resonances and those induced by driving.

17. Entanglement Spectrum of Random Unitary Circuits: S. Gopalakrishnan, J.H. Pixley, P.-Y. Chang (not at DYNQ18) and KITP postdoc X. Chen recently completed a study of entanglement spectra of random quantum circuits, focusing on the behavior of the "spectral form factor" and its time evolution for chaotic, localized, and free fermion circuits. [arXiv:1811.00029]

18. Signatures of chaos in Entanglement Spectra: T. Rakovsky, S. Gopalakrishnan, S.A. Parameswaran and F. Pollmann have developed a theory for the time evolution of entanglement spectrum level statistics of finite subsystems and used this to examine the spreading of operators and entanglement. This complements the work on entanglement spectral form factors as the finite subsystem case allows access to "lightcone" speeds in a particularly transparent fashion. A preprint is expected in early 2019.

19. Exact localized/ballistic eigenstates in chaotic ladders: T. Iadecola and M. Znidaric initiated a collaboration on studying special athermal states in Fermi-Hubbard models, that show localization despite ballistic transport in the other states. [arXiv:1811.07903]

20. Measurement-Induced Transitions: A key topic of discussion was on the role of measurement in inducing transitions in chaotic systems between area. Members of all the groups involved (R. Nandkishore, M. Pretko, A. Nahum, M.P.A. Fisher) were active participants of the program/conference, and much progress and exchange of ideas was made on this front. Three separate preprints appeared from DYNQ18 participants. [arXiv:1808.05949, arXiv:1808.05953, arXiv:1808.06134]

21. Non-Markovian dynamics in Quasiperiodic Systems and Mobile Impurity Problems: A. Freidman, R. Vasseur, A. Lamacraft and S.A. Parameswaran have developed a theory of zero-temperature dissipative dynamics of single particles in quasiperiodic backgrounds and applied it to mobile impurity problems, which can be mapped into such a setting. A preprint is expected in early 2019.

22. Fractons in Realistic Systems: R. Nandkishore, S.A. Parameswaran, and J.P. Garrahan started a collaboration on exploring lattice spin models for frustrated magnets in search of fraction behavior, and this is ongoing.

23. Kinetically Constrained models: M.-C. Banuls and J.P. Garrahan started a collaboration to apply new tensor network methods to study kinetically constrained models, and expect a paper soon.

24. Experimental protocols to measure the Hall viscosity in a rotating atomic trap: Thomas Scaffidi and Nir Navon have initiated discussions on how to measure topological invariants linked to hydrodynamics in cold atom systems.

25. Rare region effects on transport: J. Bardarson and J. Pixley initiated a collaboration studying the role of rare regions on transport in the setting of Weyl semimetals.

26. Dynamics of Quasi-1d Fermi Gases: a new collaboration on this topic was initiated between F. Heidrich-Meissner and W. Brenig

27. Kinetically Constrained Models for the MBL Transition: Working with Sthitadhi Roy and David Logan (neither at DYNQ18) J. Chalker posted a pair of preprints on Fock-space synamics of classical kinetically constrained models that exhibit features akin to the MBL transition. [arXiv:1812.06101, arXiv:1812.05115]

28. Thermalization in Conformal Field Theories with Large Central Charge: A. Dymarsky completed a preprint (w K Palenko, not at DYNQ18) on the emergence of Generalized Gibbs Ensembles in the thermodynamic limit of 2d CFTs at large central [arXiv:1810.11025]

29. Constraints on operator spreading from cluster decomposition: While at KITP, A. Dymarsky also completed work (with collaborators not at DYNQ18) examining how the spreading of operators in relativistic quantum field theories is constrained by the optimal exponent for the cluster decomposition [arXiv: 1811.03633]

30. Operator Spreading and Lieb-Robinson Bounds in Power-Law interacting systems: M. Tranh A. Gorshkov, T.Zhou, and X. Li began a collaboration exploring if new results on operator spreading in power-law interacting systems saturate some of the Lieb-Robinson-type bounds thatproved earlier or at least come closer to saturating them than any previous results.

31. Quantum State Preparation: M. Kolodrubetz developed methods for solving the short-time dynamics involved in state preparation. The goal of this project will be to test Monte Carlo methods for non-equilibrium systems against other methods and see whether they perform well for the short time but large coupling setups involved in preparing interesting states of matter. This was informed by discussions with A. Polkovnikov and M. Bukov.

32. Anomalous Floquet-Thouless Pumps: M. Koldrubetz began work on studying the properties of MBL systems in the context of using them as Thouless energy pumps. Related work on using high-frequency expansions to characterize the breakdown of MBL in cavity-coupled spin chains benefited from results presented by V. Kravtsov.

33. Dynamics of fermion systems: A. De Luca and P. Le Doussal Andrea de Luca on fermions initiated a collaboration on fermion systems under continuous monitoring.

34. Models for MBL Eigenstates: P. Le Doussal and M. Serbyn began a project focusing on developing new "tree" representations of eigenstates of many-body localized systems.

35. New Techniques for Entanglement Dynamics: P. Le Doussal, A. Nahum, and S. Vijay had fruitful exchanges on using classical mappings to the Kardar-Parisi-Zhang (KPZ) equation to study entanglement dynamics. Specific concerns included the role and universality of the initial conditions, of a finite domain size, and of dimensionality. P. Le Doussal also discussed these topics with J. Ruhman and T. Rakovszky. Two key open questions appeared to be the interpretation of the stationary measure in KPZ in the entanglement context, and the flow with time of the eigenvalues of the density matrix, from a random matrix theory point of view. As these were central topics of DYNQ18, we anticipate further progress along these directions fueled by the exchange between KPZ experts such as Le Doussal with those using KPZ to model many-body dynamics.

36. KPZ and Hydrodynamics: P. Le Doussal, R. Vasseur and M. Znidaric had discussions hydrodynamics of integrable systems and numerical evidence for the KPZ class in the Heisenberg case. This was again a fruitful exchange of two very different communities.

37. Mean-field Techniques for MBL Systems: P. Le Doussal delineated a project with Michelle Filippone using mean-field equations in presence of disorder to study MBL type effects. This is ongoing work.

38. Numerics of Sachdev-Ye-Kitaev Models: Motivated by discussions at DYNQ18, D. Luitz started work on numerical simulations of the SYK model. He has developed a high performance diagonal-zation code which is able to obtain exact central eigenpairs of the SYK4 + SYK2 model of up to 38 Majorana fermions, beyond the current state of the art. The development of this code benefited from the presence of experts, most notably T. Grover, J. Bardarson and Z. Papic, and W. Brenig.

39. Prethermal Regimes in Many-Body Systems: R. Moessner, V. Khemani, and D. Luitz initiated a collaboration on prethermal regimes in periodically driven quantum many-body systems. This work has the potential to explain recent experiments on prethermal time crystal phases in such systems. To drive this project, Luitz has developed a massively parallel exact time evolution code while at KITP to study the problem of heating and magnetization conservation in a periodically kicked quantum spin chain.

40. Dynamics of Strong Zero Modes: A. Mitra and F. Essler initiated a project on identifying strong zero modes in time-dependent and interacting Hamiltonians. This project also involves a graduate student in Mitra's group. A publication is expected soon.

41. Electron Glass Response: A long-term experimental participant, Z. Ovadyahu, benefited greatly from discussions with V. Khemani, R. Nandkishore, and I. Martin on nonlocal response in localized systems and "statistical orthogonality catastrophes" that result from such effects. Such effects might explain some puzzling results Ovadyahu's group have seen in the dynamics of Electron-glasses. They are currently engaged in further experiments to further test these theoretical ideas based on the understanding gained during these discussions.

42. Quantum Scars: Z. Papic, C. Turner, W.-W. Ho, and M. Serbyn completed a manuscript on how to enhance quantum scars, leading to a preprint [arXiv:1812.05561] written in collaboration with S. Choi, H. Pichler, A. Michailidis, D. Abanin and M Lukin. [Lukin, Abanin, and Choi were also present at DYNQ18 and/or the conference, but at different times]. The four also led a discussion on this topic. T. Scaffidi and V. Khemani were also involved in some discussions around the field of quantum scars both with these participants and with others. A contributed talk based on this work was also submitted for APS March Meeting 2019. Serbyn, Papic, and Abanin plan to apply for a focus group to meet at KITP sometime in the spring 2019, in order to continue collaboration. I. Martin and Z. Papic initiated a new collaboration studying the semiclassical limit of quantum scars. R. Nandkishore also started studying quantum scars, motivated by these talks.

43. Quantum Approximate Optimization Algorithms: Z. Papic and S. Johri, worked on understanding the relationship of this algorithm to Papic's earlier work on the "interaction distance" of quantum states. They have found some interesting connections between these two very different concepts. Their collaboration benefited from discussions with M. Bukov and A. Polkovnikov, who are also investigating the problem of quantum state preparation from different angles (e.g., reinforcement learning). At the moment, they report promising results that could lead to publications down the road.

44. Many-body localization with non-abelian symmetries: J. Pixley and A. Prakash began a collaboration to study the nature of the critical phase in many body localized systems with non-Abelian symmetries to extend some of Prakash's earlier work on the subject.

45. Entanglement Hydrodynamics in Spin Chains: T. Scaffidi and R. Vasseur made significant progress on a project exploring the time evolution of entanglement in spin chains. They expect to post a preprint soon.

46. Numerics for Driven-Dissipative Systems: A.-M. Rey and M. Szymanska compared various numerical approaches (stochastic, truncated-Wigner,…) in order to determine the best way forward for driven-dissipative systems, and have agreed to continued collaborative discussions on this topic.

47. Phase separation and first-order transitions in driven-dissipative systems: Motivated by M. Szymanska's talk at DYNQ18, she and L. Cugliandolo have initiated a collaboration in providing an analytival understanding of Szymanska's numerical results, as well as potential connections to "active matter". This has been ongoing, with visits between the two researchers, and is expected to drive new and fruitful lines of inquiry.

48. How quantum is fractonic circuit dynamics?: R. Nandkishore and Juan P. Garrahan started a collaboration aimed at extracting key aspects of the dynamics of one dimensional fractonic random circuits from classical stochastic processes. This collaboration is ongoing.

49. Fractonic dynamics in two dimensions: R. Nandkishore and S. Vijay initiated a collaboration on fractonic circuit dynamics in two dimensions. This work is ongoing.

50. Floquet localization, random tensor networks: R. Nandkishore and R. Vasseur had extensive discussions on Floquet localization and separately also on random tensor networks. These discussions are ongoing.

51. Thermalization in three dimensional fractonic systems: R. Nandkishore and F. Burnell initiated a collaboration on three dimensional fracton phases of matter. This work is ongoing.

52. Time-Dependent Variational Principles: While not a concrete collaboration, many discussions (included one organized one) centered on time-dependent variational principles for tensor network dynamics, involving S. Parameswaran, S. Gopalakrishnan, F. Pollmann, A. Green, R. Verresen, R. Vasseur, E. Altman, and several others.

Conference. A conference on *Novel Approaches to Quantum Dynamics* was held in the fourth week of the program (with Nandkishore, Vasseur, and Parameswaran serving as organizers). Several of the targeted participants who for various reasons were unable to spend extended periods at the program were able to attend the conference. Many new directions were identified, and served to frame the agenda for much of the subsequent program. The conference was also enriched by engagement with researchers from Google (S. Boixio) and IBM (S. Johri), and provided a forum for junior participants to highlight work via posters.

Efforts to increase diversity. In order to increase representation from underrepresented groups in the KITP program DYNQ18, we took the following steps starting in the early stages of the organization of the workshop. (a) In the course of submitting a proposal for this program, we advertised our workshop to a broad pool of potential applicants, including 17 women (approximately 20% of the pool). (b) We identified early on in the process key female participants: A. Chandran, L. Cugliandolo, V. Khemani and A. Mitra. Unfortunately, A. Chandran had to cancel her stay, but L. Cugliandolo, V. Khemani and A. Mitra participated for extended parts of the program. (in particular V. Khemani was a key participant who stayed for almost the whole program. She also gave the blackboard lunch talk of DYNQ18) (c) We also sent a targeted invitation to P. Cappellaro who expressed strong interest in our program. As she requested childcare support to help facilitate her 2-month visit, we requested some support from KITP as soon as possible. Similar arrangements were also coordinated for F. Burnell, where we also exercised some flexibility in admitting a shorter visit due to personal circumstances. (d) As we were sorting applications, we made sure that the ratio of female participants remains steady throughout the whole program, and well above the ratio of women in the applicant pool. (e) We separately listed several "experimentalist of the week'' women participants (Alicia Kollar accepted our invitation). (f) In addition to these efforts, we reached out to additional researchers from underrepresented groups who had not yet applied a few months after the official deadline. This allowed us to invite additional key female participants, including Fiona Burnell and Ana-Maria Rey for example.

Summary. The overall reception of the DYNQ18 program seems to have been overwhelmingly positive, with several participants remarking that it has significantly influenced their overview of the field and served to set key scientific agendas for their research. A dramatic number of new collaborations and projects have resulted from this project, the majority of which seem to be capable of leading to ongoing and sustained effort. The view of the organizers is that it was a particularly timely stage of the field to hold this workshop, and it is our collective hope that the themes explored during the 13 weeks of the program will continue to resonate in the field for some time to come.

Participant demographics

90 participants reported their gender, 12 female and 78 male

68 filled out the demographic survey. Of these:

- 5 participants, 2 of whom are US citizens, self-identified as Hispanic or Latino
- All self-identified as Asian or white; none identified as Black or Native American.
- One reported a disability

Program Participants

Participant	Participation Dates
Dr. David Aasen (KITP)	August 9 - August 17
Prof. Dmitry Abanin (Univ. of Geneva)	August 27 - October 5
Dr. Kartiek Agarwal (Princeton)	August 6 - August 24
Dr. Vincenzo Alba (SISSA)	August 6 - August 24
Dr. Ehud Altman (UC Berkeley)	August 13 - August 31
Dr. Camille Aron (ENS Paris)	October 22 - November 2
Dr. Mari Carmen Banuls (MPQ)	September 10 - September 28
Dr. Jens Bardarson (KTH)	October 8 - November 2
Mr. William Berdanier (Berkeley)	September 10 - September 28
Dr. David Berenstein (UCSB)	August 6 - November 2
Dr. Ravindra Bhatt (Princeton)	August 27 - September 7
Prof. Wolfram Brenig (TU Braunschweig)	September 24 - October 26
Dr. Marin Bukov (Berkeley)	October 15 - November 2
Prof. Fiona Burnell (Minnesota)	October 15 - October 27
Dr. Paola Cappellaro (MIT)	August 27 - October 26
Prof. John Chalker (Oxford)	August 6 - August 31
Dr. Xiao Chen (KITP)	August 6 - November 2
Dr. Yang Zhi Chou (Colorado)	August 27 - September 21
Dr. Bryan Clark (Univ. of Illinois)	September 24 - October 12
Prof. Leticia Cugliandolo (Sorbonne Univ.)	August 6 - August 24
Dr. Andrea De Luca (CNRS)	August 27 - September 7
Prof. Wojciech De Roeck (KU Leuven)	August 20 - September 7
Prof. Sebastian Diehl (Univ. of Cologne)	August 13 - August 31
Prof. Xi Dong (UCSB)	August 6 - November 2
Dr. Philipp Dumitrescu (Flatiron Institute)	August 6 - August 24
Dr. Anatoly Dymarsky (Kentucky)	October 22 - November 9
Dr. Dominic Else (MIT)	August 6 - August 24
Prof. Johanna Erdmenger (Univ. of Würzburg)	September 29 - October 16
Prof. Fabian Essler (Oxford)	August 27 - September 21
Dr. Michele Filippone (Univ. of Geneva)	September 10 - September 28
Prof. Matthew Fisher (KITP)	August 6 - November 2
Mr. Aaron Friedman (UCI)	August 6 - September 28
Prof. Juan Garrahan (Nottingham Univ.)	September 4 - September 14
Dr. Sarang Gopalakrishnan (CUNY Staten Island)	August 6 - August 31
Mrs. Anna Goremykina (Univ. of Geneva)	August 20 - September 7
Dr. Alexey Gorshkov (JQI)	August 27 - September 21
Prof. Andrew Green (UCL)	August 4 - September 1
Dr. Tarun Grover (UCSD)	October 1 - November 2
Prof. Fabian Heidrich Meisner (Univ. Goettingen)	September 2 - September 29
Dr. Wen Wei Ho (Harvard)	October 8 - November 2
Prof. Veronika Hubeny (UC Davis)	October 1 - November 2

Program Participants

Participant	Participation Dates
Dr. François Huveneers (Paris Dauphine)	August 13 - September 1
Dr. Thomas Iadecola (JQI)	September 4 - September 21
Prof. Kazi Rajibul Islam (IQC Waterloo)	August 20 - August 24
Dr. Sonika Johri (Intel)	October 22 - November 2
Prof. Mehran Kardar (MIT)	August 6 - August 24
Dr. Vedika Khemani (Harvard)	August 26 - September 1, September 15 - November 2
Prof. Igor Klebanov (Princeton)	October 22 - November 2
Dr. Alicia Kollar (Princeton)	September 10 - September 14
Dr. Michael Kolodrubetz (UT Dallas)	October 22 - November 2
Mr. Alexandre Krajenbrink (ENS Paris)	August 27 - October 19
Prof. Vladimir Kravtsov (ICTP)	October 15 - November 2
Dr. Jorge Kurchan (ENS Paris)	August 6 - August 24
Dr. Austen Lamacraft (Cambridge)	August 13 - August 24
Prof. Pierre Le Doussal (ENS Paris)	September 3 - October 19
Dr. David Luitz (TUM)	October 7 - October 25
Mr. Krishnanand Mallayya (Penn State)	August 6 - November 2
Dr. Jamir Marino (Harvard)	August 6 - August 24
Prof. Donald Marolf (UCSB)	August 6 - November 2
Dr. Ivar Martin (ANL)	October 8 - October 18
Prof. Aditi Mitra (NYU)	August 6 - September 7
Prof. Roderich Moessner (MPI-PKS)	October 14 - October 22
Prof. Joel Moore (Berkeley)	September 10 - September 28
Dr. Adam Nahum (Oxford)	September 3 - September 14
Dr. Rahul Nandkishore (Colorado)	August 26 - September 28, October 15 - November 2
Prof. Nir Navon (Yale)	October 22 - October 26
Prof. Zohar Nussinov (Washington University)	October 28 - November 3
Prof. Masaki Oshikawa (ISSP-Tokyo)	August 27 - September 21
Prof. Zvi Ovadyahu (Racah Inst.)	October 1 - October 19
Dr. Arijeet Pal (Oxford)	October 8 - November 2
Dr. Zlatko Papic (Univ. of Leeds)	October 15 - November 2
Prof. Siddharth Parameswaran (Oxford)	August 6 - September 28
Dr. Jedediah Pixley (Rutgers)	October 15 - November 2
Prof. Anatoli Polkovnikov (BU)	October 22 - November 2
Prof. Frank Pollmann (TUM)	August 6 - August 31
Mr. Abhishodh Prakash (Stony Brook)	October 15 - November 2
Prof. Peter Prelovsek (Jo?ef Stefan Inst.)	September 24 - October 12
Mr. Tibor Rakovszky (TUM)	August 6 - September 7
Prof. Mukund Rangamani (UC Davis)	October 1 - November 2
Prof. Ana Rey (Colorado)	August 20 - August 24

Program Participants

Participant	Participation Dates
Prof. Marcos Rigol (Penn State)	July 21 - September 7, October 1 - October 5
Dr. Massimiliano Rota (UCSB)	September 10 - November 2
Dr. Jonathan Ruhman (MIT)	September 18 - October 6
Prof. Lea Santos (Yeshiva Univ.)	September 10 - September 15
Dr. Thomas Scaffidi (Berkeley)	October 15 - November 2
Dr. Maksym Serbyn (IST Austria)	August 12 - September 9, October 15 - October 26
Prof. Marzena Szymanska (UCL)	August 6 - August 24
Dr. Erik Tonni (SISSA)	September 22 - October 31
Mr. Cong Minh Tran (Maryland)	August 27 - September 21
Mr. Christopher Turner (Univ. of Leeds)	October 15 - November 2
Dr. Romain Vasseur (Berkeley)	August 20 - August 31, September 17 - October 12, October 22 - November 2
Dr. Lev Vidmar (Jozef Stefan Inst.)	August 6 - September 7
Mr. Sagar Vijay (MIT)	September 10 - October 5
Dr. Curt Von Keyserlingk (Univ. Birmingham)	August 27 - October 19
Prof. Hilbert Von Löhneysen (KIT)	October 14 - October 20
Dr. Aron Wall (Stanford)	October 1 - November 2
Dr. Brayden Ware (Oxford)	August 6 - October 12
Dr. David Weiss (Penn State)	October 1 - October 5
Dr. Philipp Werner (ETH Zurich)	October 17 - November 2
Prof. Steven White (UCI)	August 13 - August 31
Dr. Dominic Williamson (Yale)	September 4 - September 21
Dr. Tianci Zhou (KITP)	August 6 - November 2
Prof. Marko Znidaric (Univ. of Ljubljana)	September 10 - October 5

Schedule of Program Talks

Speaker	Title	Date
Sarang Gopalakrishnan (CUNY)	Eigenstate entanglement and the butterfly effect in cellular automata	August 7
Vincenzo Alba (SISSA, Trieste)	Entanglement and thermodynamics after a quantum quench in integrable systems	August 7
John Chalker (Oxford)	Pedagogical Talk: Random Circuits and Many-Body Chaos	August 8
Marlena Szymanska (UCL)	Driven-dissipative superfluids: from a compact Kardar-Parisi-Zhang dynamics to a rigid state	August 9
Jamir Marino (Harvard)	Applications of time-dependent spin wave theory: chaotic dynamical ferromagnets and many-body Kapitza pendula	August 9
Frank Pollmann (TU Munich)	Discussion: Numerical Approaches to Dynamics	August 10
All Participants	Weekly organizational meeting	August 13
Dominic Else (UCSB)	Phases of matter in periodically driven systems: time crystals and beyond	August 14
Mehran Kardar (MIT)	Pedagogical Talk: KPZ	August 15
Philipp Dumitrescu (Flatiron Institute)	Slow relaxation in quasi-periodically driven random spin chains	August 16
Austen Lamacraft (Cambridge)	Noisy Coupled Qubits and the Fredrickson–Andersen Model	August 16
Leticia Cugliandolo (LPTHE, Paris)	Discussion: Quantum and Classical Glasses	August 17
Sarang Gopalakrishnan (CSI NY (CUNY))	Discussion: Quantum and Classical Glasses	August 17
All Participants	Weekly organizational meeting	August 20
Sebastian Diehl (Universität zu Köln)	Absence of Criticality in Open Floquet Systems	August 21
Rajibul Islam (University of Waterloo)	Dynamical engineering of spin-spin interaction graphs in a trapped ion quantum simulator (Experimentalist of the Week Talk)	August 22
Jorge Kurchan (LPS-ENS Paris)	Quantum bound to chaos and the semiclassical limit	August 22
Kartiek Agarwal (Princeton University)	Spatio-temporal quenches for fast preparation of ground states of critical models	August 23
Andrew Green (University College London)	The Lyapunov Spectrum of Quantum Thermalisation	August 23
Steven R. White (UC Irvine)	Discussion: Spectral Functions and Typical Thermal States with Tensor Networks	August 24
Wojciech de Roeck (TU Leuven)	Two remarks on prethermalization	September 4
Alexey Gorshkov (Joint Quantum Institute/NIST)	Information Propagation and Entanglement Generation with Long-Range Interactions	September 6
Lev Vidmar (Jozef Stefan Institute)	Entanglement entropy of eigenstates of quadratic and quantum-chaotic Hamiltonians	September 6
Juan P. Garrahan (University of Nottingham)	Discussion: Kinetically Constrained Models	September 7
Mari Carmen Bañuls (MPQ Garching)	Quantum Information, Tensor Networks and MBL	September 11
Alicia Kollar (Princeton)	Hyperbolic and Flat-Band Lattices in Circuit QED	September 12
Dominic J. Williamson (Yale)	Spurious topological entanglement entropy and subsystem symmetries in compactified cubic code	September 13
Fabian Heidrich-Meisner (Goettingen)	Nonequilibrium dynamics and transport in the 1d Fermi-Hubbard model	September 13
Adam Nahum (Oxford)	Discussion: Random Circuits	September 14
All participants	Organizational meeting	September 17
Marko Znidaric (University of Ljubljana)	Transport in 1D Lattice Models	September 18
Fabian Essler (University of Oxford)	Pedagogical Talk: Integrability	September 19
Sagar Vijay (Harvard University)	Non-hermiticity in dynamics of open quantum systems	September 20
All Participants	Organizational Meeting	September 24
Xiao Chen (UCSB)	Operator dynamics in chaotic long-range interaction systems.	September 25
Joel Moore (UC Berkeley)	Hydrodynamics	September 26
Peter Prelovsek (Ljubljana)	Many-body localization in disordered Hubbard chains	September 27
Curt Von Keyserlingk (Birmingham)	Discussion: Floquet phases and time crystals	September 28
All participants	Organizational Meeting	October 1
Bryan Clark (University of Illinois Urbana-Champaign)	Tensor networks, resonances, bulk geometry and MBL	October 2
David Weiss (Penn State University)	Dynamical Fermionization/Neutral atom quantum computing	October 3
Dmitry Abanin (University of Geneva)	Discussion: Non-ergodic phases beyond MBL	October 5
All participants	Organizational Meeting	October 8
Tarun Grover (UCSD)	Quantum correlations at finite temperature transitions	October 9
David Weld (UCSB)	Floquet band engineering and prethermalization in driven optical lattices	October 10

Schedule of Program Talks

Wen Wei Ho (Harvard)	Bounds on Energy Absorption and Prethermalization in Quantum Systems with Long-Range Interactions	October 11
All Participants	Organizational Meeting	October 15
Ivar Martin (Argonne National Lab)	Black holes and supercooled vacuum in parametrically driven electromagnetic cavities	October 16
Zvi Ovadyahu (Hebrew University of Jerusalem)	Disorder vs. Interactions in open quantum systems	October 17
Fiona Burnell (University of Minnesota)	Localization and Thermalization in constrained quantum systems	October 18
Chris Turner (Leeds)	Discussion: Quantum scars	October 19
Wen Wei Ho (Harvard)	Discussion: Quantum scars	October 19
Maksym Serbyn (IST Austria)	Discussion: Quantum scars	October 19
Zlatko Papic (Leeds)	Discussion: Quantum scars	October 19
Marin Bukov (UC Berkeley)	Reinforcement Learning: Introduction and Applications to Nonequilibrium Dynamics	October 23
Nir Navon (Yale)	Turbulence in quantum gases	October 24
Jens Bardarson (KTH)	Slow dynamics and entanglement structure in many-body localisation	October 25
Jens Bardarson (KTH)	Discussion: outlook for quantum dynamics	October 26
Vedika Khemani (Harvard)	Discussion: outlook for quantum dynamics	October 26
Rahul Nandkishore (Boulder)	Discussion: outlook for quantum dynamics	October 26
Anatoli Polkovnikov (BU)	Discussion: outlook for quantum dynamics	October 26
Romain Vasseur (UMass)	Discussion: outlook for quantum dynamics	October 26
Mike Kolodrubetz (UT Dallas)	Backaction of Floquet systems on quantized drive	October 30
Abhisodh Prakash (ICTS)	Unwinding short-range entangled phases of matter	October 31
Yaodong Li (UCSB)	Measurement-driven entanglement transition in random circuits	October 31
Vladimir Kravtsov (ICTP)	Non-ergodic extended phase and correlation-induced localization in random matrix theory.	November 1
Mike Kolodrubetz (UT Dallas)	Backaction of Floquet systems on quantized drive	November 2