MP 5: Quantum Mechanics: Spectral Theory and Many-Body Systems

Time: Wednesday 13:45–15:30 Location: KH 02.013

Invited Talk MP 5.1 Wed 13:45 KH 02.013

Nontrivial Riemann Zeros as Spectrum — •Enderalp Yakaboylu — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg

Define $\Upsilon(s) := \Gamma(s+1)\,(1-2^{1-s})\,\zeta(s)$, and denote by $\mathcal{Z} := \{\gamma \in \mathbb{C} \mid \Upsilon(\gamma) = 0\}$ its set of zeros, which includes both the periodic eta zeros, determined by $(1-2^{1-s}) = 0$ with $s \neq 1$, and the nontrivial zeta zeros ρ. We introduce a *non-symmetric* operator

$$\hat{\mathcal{R}} \colon \mathcal{D}(\hat{\mathcal{R}}) \subset L^2([0,\infty)) \to L^2([0,\infty))\,,$$

with spectrum

$$\sigma(\hat{\mathcal{R}}) = \{i\,(1/2-\gamma) \mid \gamma \in \mathcal{Z}\}\ .$$

Assuming that all nontrivial zeros of the zeta function are *simple*, we construct a positive semidefinite operator $\hat{W}$ intertwining $\hat{\mathcal{R}}$ and its adjoint on the spectral subspace associated with the nontrivial zeros,

$$\hat{\mathcal{R}}^\dagger \hat{W} = \hat{W}\hat{\mathcal{R}}\,.$$

The positivity of $\hat{W}$, which represents an operator-theoretic form of *(Bombieri's refinement of) Weil's positivity criterion*, enforces $\Re(\rho) = 1/2$ for all ρ, in accordance with the Riemann Hypothesis. Furthermore, from the similarity between $\hat{\mathcal{R}}$ and $\hat{\mathcal{R}}^\dagger$, we obtain a *self-adjoint Hilbert-Pólya operator*, whose spectrum coincides with the imaginary parts of the nontrivial zeta zeros.

The presented framework can be generalized to higher-order zeta zeros, if such exist, and to any other Mellin-transformable L-function satisfying a functional equation.

MP 5.2 Wed 14:15 KH 02.013

Wegner model in high dimension: Singular continuous spectrum from AAT self-consistency and U(1) symmetry-breaking — •Julian Arenz — Institut für Theoretische Physik, Universität zu Köln

Adopting the self-consistent theory of localization due to Abou-Chacra, Anderson, Thouless (AAT), we analyze the $N = 1$ Wegner model in high lattice dimension. By examining in detail the non-compact symmetry-breaking mechanism underlying the field theory, we uncover a new class of solutions of the AAT self-consistency equation. Their pattern of symmetry-breaking differs from the metallic and insulating solutions and naturally leads to a singular continuous spectrum of the Wegner Hamiltonian.

MP 5.3 Wed 14:30 KH 02.013

Properties of higher-order squeezing — •Felix Fischer — FAU Erlangen

Squeezed light is a corner stone of modern quantum optics, with applications ranging from increasing measurement precision at LIGO to bosonic quantum computing. Higher-order generalizations are a promising candidate for error correction schemes in continous variable quantum computing. However their well-definedness has been the subject of longstanding debate. In this talk, we show that higher-order squeezing operators become well-defined when imposing suitable boundary conditions at infinity. We observe that different boundary conditions correspond to different dynamics and ultimately different physical systems. Furthermore, we investigate the spectra, dynamics and symmetries of higher-order squeezing operators. In particular, higher-order squeezing dynamics show, opposed to usual second order squeezing, oscillatory behaviour in time.

MP 5.4 Wed 14:45 KH 02.013

Beyond the rotating-wave approximation: error bounds for higher order approximations — •Leonhard Richter[1], Robin Hillier[2], Davide Lonigro[1], and Daniel Burgarth[1] — [1]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany — [2]Department of Mathematics and Statistics, Lancaster University, UK

The rotating-wave approximation (RWA) is a widely used method for simplifying differential equations such as the Schrödinger equation in light-matter systems. However, its limitations have become more apparent with recent technological advancements highlighting the need for more sophisticated approximation schemes. Our aim is to address one particular drawback of the RWA: the error it introduces accumulates over time eventually rendering its application unjustified. In the case of bounded time-periodic Hamiltonians, the RWA is known to be the first order in the Floquet-Magnus expansion. Recently, a novel perspective on this expansion allowed to provide explicit error bounds that capture the time-dependence of each order reasonably well.

We extend this perspective to the unbounded case where the Floquet-Magnus expansion is generally not known to converge. Our approach iteratively constructs effective Hamiltonians that are time-independent in the interaction picture and scale with a specified order in frequency. Crucially, we are also able to provide explicit error bounds for the difference between the effective and original dynamics.

This work is in collaboration with Robin Hillier, Davide Lonigro, and Daniel Burgarth.

MP 5.5 Wed 15:00 KH 02.013

Renormalization of generalized spin-boson models with critical ultraviolet divergences — Benjamin Alvarez[1], Sascha Lill[2], •Davide Lonigro[3], and Javier Valentín Martín[4] — [1]Aix Marseille Univ, Univ Toulon, CNRS, CPT, Marseille, France — [2]Department of Mathematical Sciences, Universitetsparken 5, DK-2100 Copenhagen, Denmark — [3]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — [4]Universität Paderborn, Institut für Mathematik, Institut für Photonische Quantensysteme, Warburger Str. 100, 33098 Paderborn, Germany

We provide a rigorous construction of generalized spin-boson models with commuting transition matrices and form factors exhibiting critical ultraviolet (UV) divergences. That is, we cover all divergences where a self-energy renormalization, but no non-Fock representation, is required. Our method is based on a direct definition of the renormalized Hamiltonian on a sufficiently large test domain, followed by a Friedrichs extension. We then prove that this Hamiltonian coincides with the one obtained by cut-off renormalization. Furthermore, we show that for specific supercritical cases, i.e., when a non-Fock representation is required, the renormalized Hamiltonian is trivial.

MP 5.6 Wed 15:15 KH 02.013

Complexity transitions in Krylov basis for random and time-periodic unitary circuits — Himanshu Sahu[1,2,3], •Aranya Bhattacharya[4,5], and Pingal Pratyush Nath[6] — [1]Perimeter Institute for Theoretical Physics, Waterloo, ON, N2L 2Y5, Canada. — [2]Department of Physics and Astronomy and Institute for Quantum Computing,University of Waterloo, ON N2L 3G1, Canada. — [3]Department of Physics and Department of Instrumentation & Applied Physics, Indian Institute of Sciences, C.V. Raman Avenue, Bangalore 560012, India. — [4]Institute of Physics, Jagiellonian University, Lojasiewicza 11, 30-348 Krakow, Poland. — [5]School of Mathematics, University of Bristol, Fry Building Woodland Road, Bristol BS8 1UG, UK — [6]Centre for High Energy Physics, Indian Institute of Science, C.V. Raman Avenue, Bangalore 560012, India.

We study the growth and saturation of complexity in Krylov basis in random quantum circuits. In Haar-random unitary evolution, we show that, for large system sizes, this notion of complexity grows linearly before saturating at a late-time value of d/2, where d is the Hilbert space dimension, at times proportional to d. In brick-wall case, complexity in Krylov basis exhibits dynamics consistent with Haar-random unitary evolution, while the inclusion of measurements significantly slows its growth down. For Floquet random circuits, we show that localized phases lead to reduced late-time saturation values of the complexity, which we utilise to probe the transition between thermal and many-body localized phases.