universität innsbruck
Fakultät für Mathematik, Informatik und Physik

Tenure Track VORTRÄGE: „Theoretische Quantenphysik 1+2"

Seminarraum 1, ICT-Gebäude, Technikerstr. 21a

ÜBERSICHT

Mittwoch, 23.07.2025	08:30 – 09:30	**Pablo Sala de Torres Solanot** "Condensed Matter Physics in the Quantum Information Era"
	10:30 – 11:30	**Daniel Malz** "Quantum physics through the lens of computation and information"
	13:30 – 14:30	**Nicolai Friis** "Detection and characterization of entanglement in high-dimensional and multipartite systems – from theory to experiment"
	15:30 – 16:30	**Torsten Zache** "Quantum Simulation of Lattice Gauge Theories: Exploring Fundamental Physics in the Era of Quantum Information"
Donnerstag, 24.07.2025	08:30 – 09:30	**Pavel Sekatski** "Harnessing quantum effects: from foundations to applications"
	10:30 – 11:30	**N.N.** "Harnessing Collective Radiance in Sub-Wavelength Quantum Emitter Arrays"
	13:30 – 14:30	**Sofiene Jerbi** "Learning in and about the quantum world"
	15:30 – 16:30	**N.N. (online)** "New Frontiers in Quantum Sensing: From Harnessing Decoherence to Leveraging Quantum Computing"
Freitag, 26.07.2025	08:30 – 09:30	**N.N.** "Exploring quantum many-body dynamics with quantum simulation"
	10:30 – 11:30	**Ramona Wolf** "Foundations and Challenges in the Security of Quantum Key Distribution"
	13:30 – 14:30	**Dan Mao** "Shaping the Effective Descriptions of Strongly Correlated Quantum Matters: Lessons form Moiré Graphene"

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Mittwoch, 23. Juli 2025	
Pablo Sala de Torres Solanot	
08:30 – 09:05	**Forschungsvortrag:** **„Condensed Matter Physics in the Quantum Information Era“** *The rapid development of experimental quantum science platforms is enabling the exploration of novel many-body physics beyond traditional near-equilibrium settings. In this talk, I will discuss several striking non-equilibrium quantum phenomena, beginning with the fascinating problem of closed quantum many-body dynamics. We will explore how kinetic constraints can be utilized to halt quantum thermalization, leading to the phenomenon of Hilbert space fragmentation, which can be exploited to engineer highly entangled mixed states. Next, we will lower the energy of the system and consider phenomena that arise at zero temperature. We will first explore the use of (non-Abelian) topological order to store quantum information in the presence of noise, and show that this physics can be understood in terms of statistical-mechanical loop models. We will then show how even “weak” measurements can tame the rigidly universal properties emerging at quantum critical points. Drawing inspiration from quantum information science, this discovery will inform the design of optimally resilient teleportation protocols between distant labs. To conclude, we will discuss open questions in the field of quantum many-body physics.*
09:05 – 09:15	**Lehrevortrag:** **„Twin paradox”**
09:15 – 09:30	**Diskussion zu Forschungs- und Lehrevortrag**
Daniel Malz	
10:30 –11:05	**Forschungsvortrag:** **„Quantum physics through the lens of computation and information”** *Following astonishing progress in table-top quantum optics experiments, we are now entering an era of precision quantum physics. Marrying rigorous notions from computer science and quantum information theory with physical realities of building and operating quantum devices is one of the most exciting frontiers of modern quantum optics. I will argue that this not only help to build the future quantum devices, but also offers new perspectives that help us understand many-body physics and dynamics.*
11:05 – 11:15	**Lehrevortrag:** **„Twin paradox”**
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Nicolai Friis	
13:30 – 14:05	**Forschungsvortrag:** **„Detection and characterization of entanglement in high-dimensional and multipartite systems – from theory to experiment"** *Entanglement is a key resource for quantum-information processing: from basic protocols with Bell pairs of two qubits, over high-dimensional systems offering improved rates of information encoding, to entanglement shared among multiple parties with applications in future quantum networks. Yet, its characterisation and detection present complex challenges, both experimentally and theoretically.* *In this talk I will discuss some of the approaches and recent advances in the detection and certification of high-dimensional and multipartite entanglement. In particular, I will briefly review how measurements in two or more local bases can be sufficient for obtaining lower bounds on quantifiers of high-dimensional entanglement like the Schmidt number or the entanglement of formation. I will then turn to the multipartite setting, where one of the most basic insights is the fact that some mixed states can feature entanglement across every possible bipartition (they are fully inseparable), yet can be biseparable, i.e., can be produced via a mixture of partially separable states. To distinguish biseparable states from those states that genuinely cannot be produced from mixing partially separable states, the term genuine multipartite entanglement (GME) was coined, and I will explain how GME can be detected in practical experimental scenarios, e.g., in quantum-simulation experiments with qubits encoded in trapped ions or itinerant microwave photons generated from superconducting qubits.* *The premise for the distinction between fully inseparable biseparable and GME states is that only a single copy of the state is distributed and locally acted upon. However, advances in quantum technologies prompt the question of how this picture changes when multiple copies of the same state become locally accessible. In this context I will discuss recent work that shows that multiple copies unlock genuine multipartite entanglement from partially separable states.*
14:05 – 14:15	**Lehrevortrag:** **„Twin paradox"**
14:15 – 14:30	**Diskussion zu Forschungs- und Lehrevortrag**
Torsten Zache	
15:30 – 16:05	**Forschungsvortrag:** **„Quantum Simulation of Lattice Gauge Theories: Exploring Fundamental Physics in the Era of Quantum Information"** *Lattice gauge theories (LGTs) — quantum many-body models constrained by local symmetries — are central to modern theoretical physics, with applications across high-energy physics, condensed matter, and quantum information science. Yet solving LGTs remains a formidable challenge, one where quantum computing is expected to offer practical advantages over classical methods.* *In this talk, I will present recent advances in the quantum simulation of LGTs, highlighting my own contributions. These include the development of qudit-based quantum algorithms and the co-design of quantum hardware architectures tailored to the specific demands of LGTs. My work advocates for a concerted, interdisciplinary approach — one that I argue is essential for enabling large-scale quantum simulations*

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	of gauge theories. *I will conclude by outlining my broader research vision: harnessing quantum technologies to probe fundamental physics, in close synergy with and complementing ongoing efforts in Innsbruck.*
16:05 – 16:15	**Lehrevortrag:** **„Twin paradox"**
16:15 – 16:30	**Diskussion zu Forschungs- und Lehrevortrag**

Donnerstag, 24. Juli 2025	
Pavel Sekatski	
08:30 – 09:05	**Forschungsvortrag:** **„Harnessing quantum effects: from foundations to applications"** *For over a century, quantum physics has been our best theory for understanding nature and reinventing the boundaries of what is possible. In this presentation, I will focus on my own research to illustrate how quantum effects—such as coherence, entanglement, and measurement incompatibility—emerge in quantum sensing, communication, and correlations (Bell nonlocality), and how these effects can be harnessed to our advantage.*
09:05 – 09:15	**Lehrevortrag:** **„Twin paradox"**
09:15 – 09:30	**Diskussion zu Forschungs- und Lehrevortrag**
Ms. N.N.	
10:30 –11:05	**Forschungsvortrag:** **„Harnessing Collective Radiance in Sub-Wavelength Quantum Emitter Arrays"** *Sub-wavelength structured arrays of quantum emitters interacting with light represent a promising platform for exploring novel dissipative many-body quantum phenomena, and for quantum technologies applications. In these systems, the emitters couple collectively to radiation modes, leading to coherent dipole-dipole interactions and correlated radiative effects, including the enhancement or suppression of spontaneous photon emission, also known as superradiance or subradiance, respectively.* *While these phenomena have been extensively studied in cavity QED systems, where coupling is typically restricted to a small number of optical modes, here we explore a fundamentally different scenario in which emitters interact with the full three-dimensional continuum of free-space radiation modes. In this setting, interference among scattered photons can give rise to striking effects such as directional (guided) light propagation through the array and perfect reflectance of incoming photons.* *In this talk, I will discuss how these mechanisms can be harnessed for practical applications in quantum technologies, including efficient single-photon storage, photon-photon gates, and enhanced single-photon absorption. In particular, I will focus on the counterintuitive effect of how absorption can be significantly improved by the presence of decoherence mechanisms such as controlled dephasing, in combination with collective radiance. I will also outline future research directions, emphasizing potential synergies with experimental platforms.*

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11:05 – 11:15	**Lehrevortrag:** **„Twin paradox"**
11:15 – 11:30	**Diskussion zu Forschungs- und Lehrevortrag**
Sofiene Jerbi	
13:30 – 14:05	**Forschungsvortrag:** **„Learning in and about the quantum world"** *Quantum information science has made remarkable progress over recent decades, marked by advances in both the experimental realization of medium-scale quantum computers and theoretical breakthroughs in quantum information processing. Despite these achievements, major open questions persist: How can we scale quantum computers to tackle problems beyond the reach of classical computation? And where, in science and industry, can quantum technologies deliver a genuine quantum advantage?* *In this talk, I will examine how the fields of machine learning and learning theory are shaping our understanding of these pivotal questions. I will highlight recent developments that shed light onto when and how quantum algorithms can outperform classical approaches in machine learning tasks, and outline the key challenges yet to overcome for this line of research to become practically impactful. I will also examine how concepts from learning theory and machine learning techniques can deepen our understanding of the quantum world and our ability to probe and control quantum systems.*
14:05 – 14:15	**Lehrevortrag:** **„Twin paradox"**
14:15 – 14:30	**Diskussion zu Forschungs- und Lehrevortrag**
Mr. N.N. ONLINE	
15:30 – 16:05	**Forschungsvortrag:** **„New Frontiers in Quantum Sensing: From Harnessing Decoherence to Leveraging Quantum Computing"** *The ability to better interrogate the external world is crucial to unlocking novel scientific and technological breakthroughs. Quantum mechanics offers a path towards building sensors that outperform their classical counterparts, enabling us to interrogate the universe with greater accuracy, in new ways, and under novel regimes. In this talk, I will build upon this insight by expanding the landscape of opportunities for quantum sensing along two different directions.* *In the first part of my talk, I will discuss how the decoherence dynamics of a spin qubit can be used as a sensitive probe of nearby materials and used to study critical phenomena. I will briefly comment on recent experimental work demonstrating the use of this technique to study diverse physics in two-dimensional materials. In the second part of my talk, I will discuss how we can interface a quantum sensor with a quantum computer to devise new sensing protocols that outperform any conventional quantum sensing approach. Focusing on "broadband AC sensing" — the detection of a weak oscillating signal across a large frequency bandwidth — and describe a quantum computer-assisted sensing protocol whose speed saturates (up to polylogarithmic factors) a new fundamental limit set by quantum mechanics: the Grover-Heisenberg limit. I will conclude by placing these advances in a broader research program aimed at understanding how the control and manipulation of large quantum*

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	systems enables novel approaches to tackling problems in science and technology.
16:05 – 16:15	**Lehrevortrag:** **„Twin paradox"**
16:15 – 16:30	**Diskussion zu Forschungs- und Lehrevortrag**
Freitag, 25. Juli 2025	
Ms. N.N.	
08:30 – 09:05	**Forschungsvortrag**: **„Exploring quantum many-body dynamics with quantum simulation"** *In recent years, quantum simulators have become powerful tools for investigating the non-equilibrium dynamics of quantum many-body systems. They can prepare a quantum state with good fidelity and evolve it almost unitarily, preserving its coherence for sufficiently long times to observe its interacting dynamics. These advances sparked considerable theoretical interest in how isolated quantum many-body systems approach thermal equilibrium. In this talk, I will provide an overview of the current state of the field and illustrate examples of slow thermalization in quantum systems.*
09:05 – 09:15	**Lehrevortrag:** **„Twin paradox"**
09:15 – 09:30	**Diskussion zu Forschungs- und Lehrevortrag**
Ramona Wolf	
10:30 – 11:05	**Forschungsvortrag:** **„Foundations and Challenges in the Security of Quantum Key Distribution"** *Quantum key distribution (QKD) offers the remarkable advantage of enabling quantitative security proofs for practical key generation protocols - a feature absent in classical cryptography. However, the transition from theoretical cryptographic protocols to practical implementations presents significant challenges, both conceptually and technically. In this talk, I will discuss central research questions in QKD that arise at the theoretical and foundational levels, including how to rigorously connect mathematical models to realistic quantum devices, whether the assumptions underlying security proofs are physically justified, and how imperfections in devices affect security guarantees. Addressing these challenges is not only crucial for establishing trust in the security claims of quantum cryptographic protocols, but also contributes to our understanding of quantum information itself.*
11:05 – 11:15	**Lehrevortrag:** **„Twin paradox"**
11:15 – 11:30	**Diskussion zu Forschungs- und Lehrevortrag**

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Dan Mao	
13:30 – 14:05	**Forschungsvortrag:** **„Shaping the Effective Descriptions of Strongly Correlated Quantum Matters: Lessons from Moiré Graphene"** *Recent advances in tunable platforms—such as moiré materials and quantum simulators—have opened new ways to explore exotic quantum phases. Moiré graphene, in particular, has emerged as a powerful playground for discovering how strong interactions and band structure combine to produce rich many-body physics, including correlated insulators and unconventional superconductors.* *In this talk, I'll discuss two theoretical insights that arise from studying moiré systems but have broader implications for strongly correlated quantum phases of matter in general.* *First, I will introduce a mechanism I call orbital geometrical frustration, where the spatial structure of electronic orbitals imposes constraints due to strong Coulomb interaction. These constraints can stabilize insulating phases at fractional fillings and lead to intriguing properties such as charge fractionalization and hidden symmetries—drawing analogies with, but also distinctions from, frustrated magnetism.* *Second, I will present a general framework for describing how such systems respond to electromagnetic fields. Because the relevant electronic orbitals in moiré materials are spatially extended, conventional approaches to coupling effective theories to external fields must be modified, via the so-called generalize Peierls substitution. This leads to refined predictions for physical observables—such as improved upper bounds on superfluid stiffness, a key property of superconductors.*
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