Symposium One-Dimensional Quantum Many-Body Systems between Bose and Fermi Statistics (SYMB)

jointly organised by
the Quantum Optics and Photonics Division (Q) and
the Atomic Physics Division (A)

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Significant breakthroughs in the challenge to interpolate between Bose-Einstein and Fermi-Dirac statistics have recently been achieved in one-dimensional cold atomic lattice systems. Notably, a density-dependent hopping paves the way for realizing phases and phenomena that arise uniquely from anyonic statistics. Non-Abelian extensions further build a bridge to quantum information sciences. This symposium highlights recent advances and future directions in the fields of induced anyonization, Raman-dressed topological field theories, quantum spin systems, and Floquet engineering of fractional statistics.

Overview of Invited Talks and Sessions

(Lecture hall P 1)

Invited Talks

SYMB 1.1	Thu	14:30–15:00	P 1	**Exploring gauge theories for 1D anyons in Raman-coupled Bose gases** — •Leticia Tarruell
SYMB 1.2	Thu	15:00–15:30	P 1	**Non trivial particle exchange in one dimension: The anyon Hubbard model and beyond** — •André Eckardt
SYMB 1.3	Thu	15:30–16:00	P 1	**Exotic Quantum Statistics in Strongly Interacting 1D Bose Gases** — •Hanns-Christoph Nägerl
SYMB 1.4	Thu	16:00–16:30	P 1	**Dipolar gases in triangular ladders** — •Luis Santos

Sessions

SYMB 1.1–1.4	Thu	14:30–16:30	P 1	**One-Dimensional Quantum Many-Body Systems between Bose and Fermi Statistics**

Related session within the Quantum Optics and Photonics Division

Q 75.1–75.6	Fri	11:00–12:30	P 11	**Quantum Systems between Bose and Fermi Statistics**

SYMB 1: One-Dimensional Quantum Many-Body Systems between Bose and Fermi Statistics

Time: Thursday 14:30–16:30 Location: P 1

Invited Talk SYMB 1.1 Thu 14:30 P 1

Exploring gauge theories for 1D anyons in Raman-coupled Bose gases — •Leticia Tarruell — ICFO, Castelldefels (Barcelona), Spain — ICREA, Barcelona, Spain

Topological gauge theories describe the low-energy properties of certain strongly correlated quantum systems through effective weakly interacting models. A prime example is the Chern-Simons theory of fractional quantum Hall states, where anyonic excitations emerge from the coupling between weakly interacting matter particles and a density-dependent gauge field.

In my talk, I will present our experimental investigation of the chiral BF theory, a one-dimensional reduction of the Chern-Simons theory originally introduced as a gauge theory for 1D anyons. We encode it in a Bose-Einstein condensate with effective chiral interactions, which we engineer by synthesizing Raman-coupled dressed atomic states with momentum-dependent scattering properties. This allows us to reveal the key properties of the theory: the formation of chiral solitons and the emergence of an electric field generated by the system itself.

While these experiments were realized in the continuum, we have shown that applying the same scheme in an optical lattice results in a novel realization of the 1D anyon Hubbard model. In the final part of my talk, I will present the perspectives opened by this approach for investigating the many-body phase diagram of the model, as well as our current experimental progress towards realizing these ideas in the laboratory.

Invited Talk SYMB 1.2 Thu 15:00 P 1

Non trivial particle exchange in one dimension: The anyon Hubbard model and beyond — •André Eckardt — Institut für Physik und Astronomie, TU Berlin, Berlin

The anyon Hubbard model has recently been investigated experimentally both by the Greiner group in Harvard in a driven optical lattice and by the Nägerl group in Innsbruck by means of impurities. It can be represented by a bosonic tight-binding chain with number-dependent Peierls phases. I will given an introduction to the model and argue that it describes non-trivial particle exchange in one spatial dimension, associated with non-trivial Berry phases around Fock-space loops. Also its bound states in and out of the continuum will be addressed. Finally, I will discuss a recently proposed lattice model for so-called traid anyons, which are associated with the non-trivial braiding of three particles in their two-dimensional relative space.

Invited Talk SYMB 1.3 Thu 15:30 P 1

Exotic Quantum Statistics in Strongly Interacting 1D Bose Gases — •Hanns-Christoph Nägerl — Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria

Exotic quantum statistics extend beyond the familiar dichotomy of bosons, which may occupy a single quantum state, and fermions, which must each occupy different ones. Between these extremes lie anyons, allowing particles to partially share one state, and fractional Fermi seas, where particles occupy several states. My talk explores how strongly interacting 1D Bose gases provide a platform to realize unconventional statistics. I present the observation of emergent anyonic correlations induced by spin-charge separation, where a mobile impurity generates a system with a tunable statistical phase [1], providing a continuous transmutation from bosons through anyons to fermions, revealed through an asymmetric momentum-distribution and dynamical fermionization. I then report the realization of fractional Fermi seas using holonomy cycles [2,3]. Friedel-like oscillations in the one-body correlations directly expose this exotic exclusion statistics. Together, these results demonstrate a powerful and controllable route to exploring the full landscape of low-dimensional quantum statistics beyond the boson-fermion paradigm.

[1] S. Dhar et al., Observing anyonization of bosons in a quantum gas, Nature 642, 53 (2025). [2] Y. Zeng et al., Realization of Fractional Fermi Seas, manuscript in preparation. [3] M. Marciniak et al., Fermionizing the ideal Bose gas via topological pumping, arXiv:2504.19569.

Invited Talk SYMB 1.4 Thu 16:00 P 1

Dipolar gases in triangular ladders — •Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover

Experiments on dipolar quantum systems (magnetic atoms, polar molecules, Rydberg atoms) are opening interesting possibilities for the quantum simulation of spin models of interest in quantum magnetism. In particular, dipoles in triangular ladders (made with optical lattices or tweezer arrays) are characterized by the interplay between frustration and long-range interactions, allowing for the realization of intriguing phases and phase-transitions, such as a dipole-induced transition between a chiral-superfluid and a non-chiral two-component superfluid, or the realization of chiral and nematic spin phases [1]. In the spirit of the session, I will then discuss the possibilities of dipoles in triangular ladders in the context of existing proposals for anyon condensation [2].

[1] A. Dasgupta et al., arXiv:2511.07042. [2] C. D. Batista, and R. D. Somma, Phys. Rev. Lett. 109, 227203 (2012).