TT 64: BKT Physics

Time: Wednesday 16:45–18:15 Location: HSZ/0103

TT 64.1 Wed 16:45 HSZ/0103

Berezinskii-Kosterlitz-Thouless renormalization group flow at a quantum phase transition — •Matthias Thamm[1], Harini Radhakrishnan[2], Hatem Barghathi[2], Chris Herdman[3], Arpan Biswas[2], Bernd Rosenow[1], and Adrian Del Maestro[2] — [1]Leipzig University — [2]University of Tennessee, Knoxville — [3]Middlebury College, Vermont

We present a controlled numerical study of the Berezinskii-Kosterlitz-Thouless (BKT) transition in the one-dimensional Bose-Hubbard model at unit filling, providing evidence of the characteristic logarithmic finite-size scaling of the BKT transition. Employing density matrix renormalization group and quantum Monte Carlo simulations under periodic boundary conditions, together with a systematic finite-size scaling analysis of bipartite particle number fluctuations, we resolve boundary-induced complications that previously obscured critical scaling. We demonstrate that a suitably chosen central region under open boundaries reproduces universal renormalization group signatures, reconciling earlier discrepancies. Finally, leveraging a nonparametric Bayesian analysis, we determine the critical interaction strength with high precision, establishing a benchmark for BKT physics in one-dimensional quantum models.

TT 64.2 Wed 17:00 HSZ/0103

Finite-size effects in the vicinity of the BKT transition in superconducting NbN thin films — •Lea Pfaffinger[1], Alexander Weitzel[1], Sven Linzen[2], Evgenii Il'ichev[2], Ilaria Maccari[3], and Christoph Strunk[1] — [1]Department of Experimental Physics, University Regensburg, Regensburg, Germany — [2]Leibniz Institute of Photonic Technology, Jena, Germany — [3]ETH, Zurich, Switzerland

For 2D superconducting thin films, Halperin and Nelson predicted a finite resistance between the Berezinskii-Kosterlitz-Thouless temperature T_{BKT} and the mean-field critical temperature T_{c0} due to the unbinding of thermally excited vortex-antivortex pairs. Recently, we observed a sharp BKT-transition in homogeneously disordered 3nm NbN films grown by ALD, which is in very good agreement with these theoretical predictions [1]. Although the sample width was much smaller the Pearl length $\Lambda_p \approx 2mm >> \mathrm{w} = 10\mu m$, we did not observe a size induced smearing of the transition. When further reducing the width to $\mathrm{w} \leq 1\mu m$, we do observe a finite resistance for $T < T_{BKT}$ as expected from the cut-off of the divergence of the correlation length by the finite size. This resistance is thermally activated with an activation energy that depends logarithmically on the width. We present a systematic study of the resistance in this regime combined with an analysis based on the work of [2] and [3].

[1] A. Weitzel et al., Phys. Rev. Lett. 131, 186002 (2023).
[2] L. Benfatto et al., Phys. Rev. B 80, 214506 (2009).
[3] V.G. Kogan et al., Phys. Rev. B 83, 144526 (2011).

TT 64.3 Wed 17:15 HSZ/0103

Quasi-two-dimensional superconductivity in 1T-$Ti_{1-x}Ta_xSe_2$ — •Poulami Manna, Suhani Sharma, Tarushi Agarwal, Shashank Srivastava, Priya Mishra, and Ravi Prakash Singh — Indian Institute of Science Education and Research, Bhopal

The emergence of two-dimensional (2D) superconductivity in bulk transition metal dichalcogenides (TMDs) has sparked crucial research interest for hosting exotic quantum states. Intercalation, doping, or inserting insulating layers can significantly weaken the interlayer coupling, thereby achieving 2D behavior in bulk materials. While doped bulk crystals of TaS_2 and $NbSe_2$ show 2D superconductivity, Ti-based TMDs remain largely unexplored. Among them, non-superconducting $TiSe_2$ has been extensively studied due to its controversial electronic nature and semimetallic/semiconducting behavior.

Here, we discuss the superconducting properties of single-crystalline 1T-$Ti_{1-x}Ta_xSe_2$ for $x = 0.2$, using magnetization, resistivity, and specific heat measurements. The results reveal anisotropic bulk superconductivity with a transition temperature of 2.32(1) K. Specific heat measurements show weakly coupled, isotropic s-wave superconductivity in $Ti_{0.8}Ta_{0.2}Se_2$. Notably, the first evidence of quasi-2D superconductivity in Ti-based TMD is confirmed by angle-dependent magneto-transport measurements and observation of a BKT transition. These findings offer an opportunity to explore numerous low-dimensional quantum phases in bulk materials and effectively broaden the new pathway for realizing 2D superconductivity.

TT 64.4 Wed 17:30 HSZ/0103

Two-dimensional multiband superconductivity in 1T-MoS_2 — •Chithra H. Sharma[1,2] and Madhu Thalakulam[2] — [1]Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany — [2]IISER Thiruvananthapuram, 695551 Thiruvananthapuram, India

van der Waals materials provide ultra-clean platforms to realise superconductivity in 2D, which is decorated by features such as Berezinskii-Kosterlitz-Thouless (BKT) phase transition and Bose metal phase owing to the vortex dynamics in the system. One interesting yet seldom-studied material is 1T-MoS_2, the metallic phase. Stable 1T-MoS_2 prepared using Ar/H_2 microwave plasma exposure shows 2D superconductivity with a critical temperature of ∼920 mK. BKT phase transition, Bose metal phase and enhanced parallel critical field above the Pauli limit have been observed in the system. The low-noise differential I-V characteristics of the sample show features corresponding to multiband superconductivity.

TT 64.5 Wed 17:45 HSZ/0103

Phases of Quasi-One-Dimensional Fractional Quantum (Anomalous) Hall Superconductor Heterostructures — Steffen Bollmann[1], Andreas Haller[2], Jukka I. Väyrynen[3], •Thomas L. Schmidt[2], and Elio J. König[4,1] — [1]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]University of Luxembourg, L-1511 Luxembourg, Luxembourg — [3]Purdue University, West Lafayette, Indiana 47907, USA — [4]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA

We study fractional quantum (anomalous) Hall-superconductor heterostructures in the presence of $U(1)$ order-parameter fluctuations and focus on the case of $\nu = 2/3$ quantum Hall states leading to $\mathbb{Z}_3$ parafermions. For an alternating pattern of superconductor and tunneling regions, coupled to fractional quantum Hall edge states, we use a map onto a topological Josephson junction chain involving lattice parafermions. Using DMRG simulations, we establish a phase diagram composed of Mott insulating phases and two different Luttinger liquids carrying excitations with charges $2e$ and $2e/3$. In agreement with analytical considerations using conformal field theory, we numerically find transitions of Berezinskii-Kosterlitz-Thouless (BKT) type as well as a continuous $\mathbb{Z}_3 \times U(1)$ second-order phase transition characterized by central charge $c = 9/5$. We finally extract information about a possible ground state degeneracy and comment on the stability of parafermionic edge states in the presence of order parameter fluctuations.

TT 64.6 Wed 18:00 HSZ/0103

Persistence of the Berezinskii-Kosterlitz-Thouless transition with long-range couplings — •Luis Walther[1,2], Josef Willsher[1,3,2], and Johannes Knolle[1,3,4] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [4]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

The Berezinskii–Kosterlitz–Thouless (BKT) transition is an archetypal example of a topological phase transition, which is driven by the proliferation of vortices. In this Letter, we analyze the persistence of the BKT transition in the XY model under the influence of long-range algebraically decaying interactions of the form $\sim 1/r^{2+\sigma}$. The model hosts a magnetized low temperature phase for sufficiently small σ. Crucially, in the presence of long-range interactions, spin waves renormalize the interaction between vortices, which stabilizes the BKT transition. As a result, we find that there is no direct transition from the magnetized to the disordered phase and that the BKT transition persists for arbitrary long-range exponents, which is distinct from previous results. We use both Landau–Peierls-type arguments and renormalization group calculations—including a coupling between spin wave and topological excitations—and obtain similar results. We discuss the relevance of our findings for current Rydberg atom experiments, and highlight the importance of long-range couplings for other spin models.