# TT 63: Topology: Quantum Hall Systems

Time: Wednesday 15:00–16:45 Location: A 053

TT 63.1 Wed 15:00 A 053

**Strain-Induced Landau Levels in Arbitrary Dimensions with an Exact Spectrum** — •Stephan Rachel[1], Ilja Goethel[2], Daniel P. Arovas[3], and Matthias Vojta[2] — [1]University of Melbourne, School of Physics — [2]TU Dresden, Institut für Theoretische Physik — [3]UC San Diego, Department of Physics

Certain nonuniform strain applied to graphene flakes has been shown to induce pseudo-Landau levels in the single-particle spectrum, which can be rationalized in terms of a pseudomagnetic field for electrons near the Dirac points. However, this Landau level structure is, in general, approximate and restricted to low energies. Here, we introduce a family of strained bipartite tight-binding models in arbitrary spatial dimension $d$ and analytically prove that their entire spectrum consists of perfectly degenerate pseudo-Landau levels. This construction generalizes the case of triaxial strain on graphene's honeycomb lattice to arbitrary $d$; in $d = 3$, our model corresponds to tetraxial strain on the diamond lattice. We discuss general aspects of pseudo-Landau levels in arbitrary $d$.

TT 63.2 Wed 15:15 A 053

**Properties of the one-particle density matrix in an interacting Chern insulator** — Andrew Hayward[1], Marie Piraud[2], and •Fabian Heidrich-Meisner[2,3] — [1]LMU Munich, Germany — [2]TU Munich, Germany — [3]Georg-August-University Goettingen, Germany

The notion of a topological insulator is rooted in the physics of non-interacting particles but generalizes to interacting systems. Here we investigate how much of the topological properties of an interacting Chern insulator is encoded in the single–particle quantities derived from the one-particle density matrix (OPDM) computed in the many-body ground state. The diagonalization of the OPDM yields the occupation spectrum and its eigenfunctions. In a concrete example, we study how the occupations evolve as a function of interactions and how the eigenfunctions are deformed away from the non-interacting limit. After resolving potential ambiguities in defining OPDM eigenbands, we compute the Chern numbers for these emergent OPDM bands, which are necessarily quantized. The behavior of these quantities, occupations, OPDM eigenfunctions, and OPDM Chern numbers, across a transition into a topologically trivial phase is discussed.

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TT 63.3 Wed 15:30 A 053

**Emergent Chern-Simons excitations due to electron-phonon interaction on hexagonal lattices** — •Andreas Sinner and Klaus Ziegler — Institut für Physik, Theorie II Universität Augsburg Universitätsstr. 1 D-86159, Augsburg, Germany

We address the problem of Dirac fermions interacting with inplane optical phonons. A gap in the spectrum of fermions leads to the emergence of the Chern-Simons excitations in the spectrum of phonons. We study the effect of those excitations on observable quantities: the phonon dispersion, the phonon spectral density, and the Hall conductivity.

[1] A. Sinner, K. Ziegler, Phys. Rev. B 93, 125112 (2016).

TT 63.4 Wed 15:45 A 053

**Protected pseudohelical edge states in $Z_2$-trivial proximitized graphene** — •Tobias Frank, Petra Högl, Martin Gmitra, Denis Kochan, and Jaroslav Fabian — Universität Regensburg

We investigate topological properties of models that describe graphene on realistic substrates which induce proximity spin-orbit coupling in graphene [1]. A Z2 phase diagram is calculated for the parameter space of (generally different) intrinsic spin-orbit coupling on the two graphene sublattices, in the presence of Rashba coupling. The most fascinating case is that of staggered intrinsic spin-orbit coupling which, despite being topologically trivial, $Z_2$=0, does exhibit edge states protected against time-reversal scattering for zigzag ribbons as wide as micrometers. We call these states pseudohelical as their helicity is locked to the sublattice. The spin character and robustness of the pseudohelical modes is best exhibited on a finite flake, which shows a finite spin current in the crossection of the flake, and exhibit spin-flip reflectionless tunneling at the armchair edges.

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[1] M. Gmitra, D. Kochan, P. Högl, J. Fabian, PRB 93 155104 (2016)

TT 63.5 Wed 16:00 A 053

**Topological edge states in graphene from proximity effect** — •Petra Högl, Tobias Frank, Denis Kochan, Martin Gmitra, and Jaroslav Fabian — Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

Placing graphene on transition-metal dichalcogenides can increase its spin-orbit coupling by orders of magnitude [1] and leads to the formation of edge states protected against time-reversal scattering in zigzag ribbons [2]. We investigate an effective model for such systems in the presence of proximity-induced exchange splitting [3], which breaks time reversal symmetry and allows for quantum anomalous Hall states. We show the chiral edge states for zigzag and armchair ribbons and prove their topological character by computing the Chern number. From the bulk gap closing and Chern number for a wide parameter space of staggered intrinsic spin-orbit coupling and uniform exchange splitting (and vice versa) we identify distinct topological phases with Chern number $\pm 2$ ($\pm 1$). By adding proximity-induced s-wave superconductivity to the system we get particle-hole symmetric doubling of the number of edge states and topological superconducting phases with Chern number $\pm 4$ ($\pm 2$). This work is supported by IDK Top. Ins. of ENB, DFG SFB 689, GRK 1570, and by the EU Seventh Framework Prog. under Grant Agreement No. 604391 Graphene Flagship.

[1] M. Gmitra, D. Kochan, P. Högl, J. Fabian, Phys. Rev. B 93, 155104 (2016)
[2] T. Frank, P. Högl, M. Gmitra, D. Kochan, J. Fabian, arXiv: 1707.02124
[3] K. Zollner, M. Gmitra, T. Frank, J. Fabian, Phys. Rev. B 94, 155441 (2016)

TT 63.6 Wed 16:15 A 053

**Chiral Topological Phases from Artificial Neural Networks** — Raphael Kaubruegger[1,3], •Lorenzo Pastori[1,2], and Jan Carl Budich[1,2] — [1]Department of Physics, University of Gothenburg, SE 412 96 Gothenburg, Sweden — [2]Institute of Theoretical Physics, Technische Universitaet Dresden, 01062 Dresden, Germany — [3]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria

Motivated by recent progress in applying techniques from the field of artificial neural networks (ANNs) to quantum many-body physics, we investigate as to what extent the flexibility of ANNs can be used to efficiently study systems that host chiral topological phases such as fractional quantum Hall (FQH) phases. With benchmark examples, we demonstrate that training ANNs of restricted Boltzmann machine type in the framework of variational Monte Carlo can numerically solve FQH problems to good approximation. Furthermore, we show by explicit construction how n-body correlations can be kept at an exact level with ANN wave-functions exhibiting polynomial scaling with power n in system size. Using this construction, we analytically represent the paradigmatic Laughlin wave-function as an ANN state.

TT 63.7 Wed 16:30 A 053

**Charge and energy fractionalization mechanism in one-dimensional channels** — •Matteo Acciai[1,2,3], Alessio Calzona[1,2,4], Giacomo Dolcetto[4], Thomas L. Schmidt[4], and Maura Sassetti[1,2] — [1]Dipartimento di Fisica, Università di Genova, Via Dodecaneso 33, 16146 Genova, Italy — [2]SPIN-CNR, Via Dodecaneso 33, 16146 Genova, Italy — [3]CNRS, CPT, Aix Marseille Université, Université de Toulon, Marseille, France — [4]Physics and Materials Science Research Unit, University of Luxembourg, L-1511, Luxembourg

We study the problem of injecting single electrons into interacting one-dimensional quantum systems, a fundamental building block for electron quantum optics. It is well known that such injection leads to charge and energy fractionalization. We elucidate this concept by calculating the nonequilibrium electron distribution function in the mo-

mentum and energy domains after the injection of an energy-resolved electron. Our results shed light on how fractionalization occurs via the creation of particle-hole pairs by the injected electron. In particular, we focus on systems with a pair of counterpropagating channels, and we fully analyze the properties of each chiral fractional excitation which is created by the injection. We suggest possible routes to access their energy and momentum distribution functions in topological quantum Hall or quantum spin-Hall edge states.

[1] Phys. Rev. B **94**, 035404 (2016)
[2] Phys. Rev. B **96**, 075144 (2017)