# Thomas G. Kiely


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| Publication Lists: | Google Scholar, ORCID |


## Education

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|---|---|
| Aug. 2018 – Present | Ph.D. in Physics<br>**Cornell University**<br>Thesis Advisor: Erich Mueller |
| Aug. 2018 – Mar. 2021 | M.S. in Physics<br>**Cornell University** |
| Aug. 2014 – May 2018 | B.S. in Physics, B.A. in Italian, Minor in Philosophy<br>**Georgetown University**<br>*Summa Cum Laude*<br>GPA: 3.96 Overall; 4.0 Physics; 4.0 Italian |
| Senior Thesis | *Quantum Simulators with Trapped Ions: Two Examples*<br>Thesis Advisor: James Freericks |
| Aug. 2016 – Dec. 2016 | Semester at **University of Bologna**<br>Direct Matriculation<br>GPA: 4.0 (equivalent) |

## Honors and Awards

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| May 2018 | **Undergraduate Research Award** for depth and impact of written and oral presentation of undergraduate senior thesis |
| May 2018 | **Kidwell Medal** for excellence in undergraduate Physics coursework |
| May 2018 | **Dante Award** for excellence in undergraduate Italian coursework |
| May 2018 | **Phi Beta Kappa** |
| April 2013 | **National Merit Finalist** |

## Research Experience

Aug. 2018 – Present

**Laboratory of Atomic and Solid State Physics, Cornell University**
Graduate Research Assistant with Erich Mueller

- I studied the thermoelectric transport of weakly-interacting two-component fermions in a clean optical square lattice with the goal of understanding recent cold atom experiments. Notably, I found a number of "unconventional" features that arise in this relatively conventional setting. This has direct implications for the study of strongly-correlated systems in ultracold atom experiments, as it informs what they should be benchmarked against – one cannot identify strongly-correlated behavior without a proper comparison to the contrasting limit. From a technical standpoint, this work made use of the linearized Boltzmann equation (which we solve variationally) in concert with Fermi's golden rule. I also explored ways to renormalize the interaction strength with the Gutzwiller approximation at finite temperatures, although this does not appear in our paper.

- In a collaboration with Brad Ramshaw's group, I modeled the behavior of ultrasound attenuation across the superconducting transition temperature in unconventional superconductors. Their measurements show that the ultrasound attenuation in $Sr_2RuO_4$ increases below the transition when conventional ($s$-wave BCS theory) calculations say it should decrease. I determined that inversion-symmetry-breaking superconducting gaps (e.g. triplet gaps) can result in such a peak, but that the height and width of the peak is not consistent with their measurements. I performed similar calculations for a variety of superconducting gap functions, ruling out alternative explanations (including pair-breaking). The principal conclusion of our paper is that the peak they observed is most likely due to fluctuations in domain walls between spatial regions with accidentally degenerate superconducting order parameters.
- I studied the superfluid properties of strongly-interacting lattice bosons in the thermodynamic limit. In one dimension these bosons cannot condense, but they nevertheless exhibit characteristic superfluid phenomenology in their Luttinger liquid phase. In our paper, we explain the relationship between this behavior and clean metallic behavior in one dimension as well as experimental constraints to observing these features. We then show that the properties of this gapless phase can be efficiently studied using a hierarchy of matrix product states, with a particular focus being given to conformal scaling relations and the virtual dimension is increased. Our simulations made use of the recently-developed VUMPS algorithm for working efficiently in the thermodynamic limit.
- The above investigation inspired a follow-up study of the role of sparsity constraints in infinite matrix product states (iMPS). In particular, physically-motivated conservation laws (e.g. particle number conservation) manifest themselves as block-sparsity constraints on the matrix structure of an MPS. For closed, finite-sized systems, such constraints are indispensable for realistic modeling. In the thermodynamic limit, however, spontaneous symmetry-breaking is (in principle) allowed, posing the following question: are such constraints "helpful" for numerical simulations in the thermodynamic limit? The most interesting application of this question is to Luttinger liquids, which are gapless, critical, symmetry-preserving phases. I found that the ratio of leading-order energy corrections with and without sparsity collapses onto a scaling function of the Luttinger parameter, $K$, indicating that the universal relationship between number fluctuations and $K$ is manifest in the scaling properties of iMPS. I furthermore quantified a number of other experimentally-relevant distinctions between the *ansätze*, indicating a region in parameter space where sparsity constraints are detrimental to numerical performance.

Jan. 2015 – May 2018 | **Georgetown University**
Undergraduate Research Assistant with James Freericks

- I studied a stroboscopic mapping between the transverse-field Ising model and the XY model that has been used in trapped-ion simulators. We demonstrated how this arises due to the rotating wave approximation and put experimental bounds on its utility. This involved exact diagonalization of finite-sized Hamiltonians, degenerate perturbation theory, and calculation of Green's functions to develop experimental constraints.
- I modeling the kinetics of a trapped-ion Coulomb crystal transitioning between two locally-stable conformations, which was realized by Wes Campbell's experimental group. I developed a method to find minimum energy (classical) path in high-dimensional configurational space and used Markov analysis to determine the temperature from their experimental data.

June 2016 – Aug. 2016 | **Institute for Molecular Engineering, University of Chicago**
Undergraduate Research Assistant with David Awschalom

- I set up optical experiments involving long-time coherent quantum states in defects of $SiO_2$. My responsibilities included assembling optical table, writing message-based drivers in Python, and designing a custom magnet-bearing goniometer in SolidWorks.

## Teaching Experience

Spring 2022 | PHYS-2213: Physics II: Electromagnetism
Course Instructor: Alan Giambattista (Cornell)
Lead three discussion sections and twice weekly office hours, graded homework, proctored and graded exams

Fall 2020 | PHYS-2213: Physics II: Electromagnetism
Course Instructor: Ivan Bazarov (Cornell)
Course held entirely online; lead three discussion sections and twice weekly office hours, graded homework, proctored and graded exams

Spring 2020 | PHYS-1102: General Physics II
Course Instructor: Nick Taylor (Cornell)
Staffed a flipped, self-taught classroom for 15hrs per week, set up student-run labs, graded lab notebooks, proctored and graded exams. Taught extensively over Zoom due to COVID-19

Spring 2019 | PHYS-2208: Fundamentals of Physics II
Course Instructor: Glenn Case (Cornell)
Lead two discussion sections and a lab section, created weekly quizzes, graded homework, proctored and graded exams

Fall 2018 | PHYS-1101: General Physics I
Course Instructor: Nick Taylor (Cornell)
Staffed a flipped, self-taught classroom for 15hrs per week, set up student-run labs, graded lab notebooks, proctored and graded exams

Fall 2017 | PHYS-251: Intermediate Mechanics
Course Instructor: Peter Olmsted (Georgetown)
Held office hours, lead a weekly tutorial, graded problem sets, proctored exams

Fall 2015 | PHYS-153: Relativity and Quantum Physics
Course Instructor: Joseph Serene (Georgetown)
Held office hours, graded problem sets

## Publications

5. *Role of conservation laws in the density matrix renormalization group*
   **TGK** and Erich J. Mueller
   Phys. Rev. B **106**, 235126 (2022)
   arXiv:2207.03465
4. *Strong Increase in Ultrasound Attenuation Below $T_c$ in $Sr_2RuO_4$: Possible Evidence for Domains*
   Sayak Ghosh, **TGK**, Arkady Shekhter, F. Jerzembeck, N. Kikugawa, Dmitry A. Sokolov, A. P. Mackenzie and B. J. Ramshaw
   Phys. Rev. B **106**, 024520 (2022)
   arXiv:2109.00041
3. *Superfluidity in the one-dimensional Bose-Hubbard model*
   **TGK** and Erich J. Mueller
   Phys. Rev. B **105**, 134502 (2022)
   arXiv:2202.0066
2. *Transport in the 2D Fermi-Hubbard Model: Lessons from Weak Coupling*
   **TGK** and Erich J. Mueller.
   Phys. Rev. B **104**, 165143 (2021) *[Editor's Suggestion]*
   arXiv:2106.04479
1. *Relationship between the transverse-field Ising model and the XY model via the rotating-wave approximation*
   **TGK** and J. K. Freericks
   Phys. Rev. A **97**, 023611 (2018)
   arXiv:1711.04386

## Press on Research

Phys. Rev. B **104**, 165143 (2021) *[Editor's Suggestion]*

- "Weak coupling shows flaw in strange metal model" (Cornell Chronicle)
- "Weak coupling shows flaw in strange metal model" (Phys.org)

## Conference Talks and Posters

**TGK** and Erich J. Mueller. "Transport in the 2D Fermi-Hubbard Model: Lessons from Weak Coupling." (Poster)
- ICAP, Jul. 18-22, 2022, Toronto, ON

**TGK** and Erich J. Mueller. "Superfluidity in the 1D Bose-Hubbard model." (Poster and Contributed Talk)
- APS March Meeting, Mar. 14-18, 2022, Chicago, IL

**TGK** and Erich J. Mueller. "Superfluidity in the 1D Bose-Hubbard model." (Poster)
- Boulder School for Condensed Matter and Materials Physics: Ultracold Matter, Jul. 5-30, 2021, Boulder, CO

**TGK** and Erich J. Mueller. "Umklapp Scattering gives rise to T-Linear Resistivity in the Hubbard Model." (Poster)
- ARO/AFOSR MURI Quantum Matter Grant Review, Oct. 15, 2019, Amherst, MA

## Preprints and Unpublished Research

- *Anomalous Resistivity at Weak Coupling*
  **TGK** and Erich J. Mueller
  arXiv:2108.11428

## Extracurricular Activities

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| April 2020 | Cornell Expanding Your Horizons Conference<br>Workshop Co-Leader: "Physics of Bubbles" |
| Aug. 2014 – May 2018 | Georgetown Men's Varsity Lightweight Rowing |
| Aug. 2014 – May 2018 | Georgetown Circolo Italiano<br>Treasurer (2017-2018) |
| June 2015 – Dec. 2015 | Georgetown Physics Peer Advisor |

## Technical Skills

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| Programming Languages | Python, C++, Julia, Java, Mathematica |
| CAD | SolidWorks |

## Languages

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| English: | Native |
| Italian: | Fluent (non-Native) |