Miguel Ornedo Mercado

Curriculum Vitae
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Research Interests: Condensed Matter Theory, Many-Body Physics, Non-Equilibrium Dynamics, Quantum Information

Education

University of Southern California 2020 - Present
B.A. in Physics & B.A. in Mathematics
Primary Advisor: Stephan Haas

Relevant Coursework

- *Graduate (12 Completed)*:

PHYS 558a: Advanced Quantum Mechanics I
PHYS 508ab: Advanced Electricity and Magnetism I/II
PHYS 518: Thermodynamics and Statistical Physics
PHYS 516: Methods of Computational Physics
PHYS 513: Applications of Quantum Computing
PHYS 550: Theory of Open Quantum Systems
PHYS 558b: Advanced Quantum Mechanics II
PHYS 504: Advanced Mechanics
PHYS 559: Quantum Devices
PHYS 510: Methods of Theoretical Physics
PHYS 678: Relativistic Quantum Field Theory (IP)
MATH 540: Algebraic Topology

- *Undergraduate*: PHYS 161: Analytical Mechanics, PHYS 162: Electricity and Magnetism (with Special Relativity), PHYS 499: Intro to Quantum Field Theory (*listed as Special Topics*)

Publications

[3] P. Lammert, M. Mercado, V. Crespi. A Probabilistic Foundation for Cluster Expansion (2025). (in prep for submission: Phys. Rev. Research; link to prior version: arXiv:2210.10937).

[2] M. Mercado, K. Reyes, A. Prem, A. Nakano, R. Di Felice, S. Haas. Simulating one-dimensional Floquet topology on a noisy quantum processor (2025). (in prep for submission: Phys. Rev. Lett.).

[1] M. Mercado, K. Chen, P. H. Darekar, A. Nakano, R. Di Felice, and S. Haas. Dynamics of symmetry-protected topological matter on a quantum computer. Phys. Rev. B **110** (7), 075116 (2024).

Research

University of Southern California (with Institute of Advanced Study)
Advisors: Dr.(s) Abhinav Prem, Stephan Haas April 2024 - Present

- Observation of Floquet Chiral Symmetry Protection on a Noisy Quantum Processor
  - Led problem conception and end-to-end implementation of Floquet topological insulators on digital cloud quantum hardware, providing a testbed to study dissipation in periodically-driven systems
  - Demonstrated chiral-symmetric Floquet driving protocols can protect qubit coherence times up to unprecedented timescales without error mitigation (> 500 simulation timesteps in units of inverse energy), resulting in research paper Ref. [2]
  - Characterized open quantum system evolution of topological Floquet Hamiltonians with symmetry breaking time disorder via numerical calculation and hardware fermionic sublattice number signature validation
  - Leading writing and editing of Ref. [2] for submission to *Phys. Rev. Lett.* **[in final stages of prep.]**
- Stabilizing One-Dimensional Dipolar Symmetry-Protected Topological (SPT) Phases
  - Numerically characterized Lindblad dynamics of string order parameter in $\mathbb{Z}_3$ Cluster/Dipole SPT states
  - Presently: analytically developing novel local correction protocol exacting strong $\mathbb{Z}_3 \times \mathbb{Z}_3$ model symmetry

Massachusetts Institute of Technology
MIT Summer Research Program (MSRP) | Advisor: Dr. Luqiao Liu June 2023 - Jan 2024

- Phenomenology of Chiral Magnons in NV-YIG Multilayers
  - Derived lattice model exhibiting engineered spin-spin entanglement within tunable hybrid quantum multilayer structure via guided chiral magnons, identifying a pathway towards magnon-mediated many-body entanglement for protected quantum information processing

- Analytically derived effective Hamiltonian for NV-magnon interaction of Yttrium Iron Garnet (YIG) and Nitrogen Vacancy (NV) bilayers; derived interaction energies within NV-YIG multilayers
- Proposed theory to describe experimental observation of magnon unidirectionality in YIG films via induced time-reversal symmetry breaking in out-of-plane phase correlations of interacting local spins in antiferromagnetic bilayers; presented at 2023 MSRP Symposiums and Bryn Mawr Colloquium (see *Presentations*)

University of Southern California
Advisors: Dr.(s) Aiichiro Nakano, Rosa Di Felice, Stephan Haas Jan 2023 - Apr 2024

- Dynamics of Symmetry-Protected Topological (SPT) Matter on a Quantum Computer
  - Led problem conception and collaboration to probe long-time open quantum system equilibration dynamics of topological insulators via digital noisy intermediate scale hardware
  - Designed new protocol to implement time evolution of topological insulators for arbitrary time-step amount via constant-depth quantum circuits, culminating in the first long-time dynamics realization of SPT-insulating matter on superconducting quantum processors (Ref. [1])
  - Performed analytical calculations via fermionic Bogoliubov-de Gennes (BdG) approach to phenomenologically characterize experimentally observed signatures of topological localization in system magnetization
  - Directed the writing, editing, and acceptance of research publication Ref. [1] to *Phys. Rev. B* on behalf of the research team [**Awarded Top Presentation at 2024 APS March Meeting**]

University of Southern California
Advisor: Dr. Stephan Haas

- Topological Witnesses in Disordered Chiral Symmetric Matter Jan 2023 - Aug 2023
  - Investigated response of topological protection and persistence of topological remnants against on-diagonal and off-diagonal disorder in topological insulator models via numerical computation of disorder-averaged electronic band structure, density of states, and wavefunction imaging
  - Performed analytical calculations of the real-space multi-band winding number with modulated disorder strengths, providing evidence for a hierarchy of topological surface modes within extended Su-Schrieffer-Heeger (SSH) models in the presence of disorder [**Awarded Best Overall Presentation at USC Symposium for Creative and Scholarly Work**]
  - Studied scaling behavior of localized zero modes as a response to extreme disorder, pointing towards a discovered "Dyson singularity" phase exhibiting logarithmic growth of localization
- Topological Quantum Field Theories (TQFTs) of Quantum Matter (*reading project*) June 2022 - May 2023
  - Explored applications of 2+1 dimensional TQFTs to the description of two types of matter: systems exhibiting intrinsic topological order (fractional quantum Hall states and toric code), and systems with topological protection corresponding to the conservation of global symmetries (SPT phases) via Chern-Simons theories
  - Investigated mathematical relationship between topological error correcting codes and effective field theories, culminating in two produced projects available online to read: 1. 3d gauge Ising model as string theory *(with Dr. Scott MacDonald)*, 2. 2d Topological Quantum Field Theories and Frobenius Algebras

The Pennsylvania State University
NSF REU Student, Condensed Matter Theory Group | Advisor: Dr. Paul Lammert May 2022 - Dec 2022

- Geometrical Reformulation of the Cluster Expansion Method
  - Contributed to formal reformulation of the mathematical foundation of the Cluster Expansion Method used to extend statistical mechanical computations to multi-component materials (e.g. alloys) via reinterpreting cluster components as Möbius inversion of conditional expectation; affirmed by numerical trials (Ref. [3])]
  - Author of Geometrical Cluster Expansion Package (GCEP), a modular Python software package which numerically extends the revised formalism using an algorithmic approach based in Hilbert Space geometry

Scholarships, Honors, & Awards

- Astronaut Scholarship *for national excellence in research (Amount: $15,000)* 2024
- Susan and Jim Walsh Scholarship *for academic excellence as low-income college student (Amount: $5,500)* 2024
- GSMI Scholar | *Cientifico Latino Graduate Student Mentorship Initiative* 2024
- Top Presenter Award *for oral presentation at 2024 APS March Meeting, Minneapolis MN* 2024

- Barry Goldwater Scholarship National Finalist | *University of Southern California Nominee* 2023
- Best Overall Presentation *for poster at USC Symposium for Scholarly and Creative Work (Amount: $500)* 2023
- Pathways to Science *Student Spotlight feature as "Rising Star in Condensed Matter and Theoretical Physics"* 2023
- Provost's Undergraduate Research Fellowship Award (*Amount: $6,000 over six semesters*) 2022-2024
- USC Undergraduate Research Associates Program (URAP) Fellowship (*Amount: $1,000*) 2022
- John Trout Memorial Scholarship *for civic and academic excellence (Amount: $5,000)* 2020
- Social Studies Student of the Year Departmental Award *for community organizing efforts* 2020
- U.S. Board of Education Awardee, Cook County IL *for academic excellence* 2019

Presentations

Oral Presentations

- M. Mercado, K. Chen, P.H. Darekar, A. Nakano, S. Haas, "Dynamics of Symmetry-Protected Topological Phases of Matter on a Quantum Computer," talk at APS March Meeting (2024)
  - **Top Presenter Award**, Future of Physics Days
- M. Mercado,"Donuts & Faucets: Topology in Physics," talk at USC Undergraduate Researcher's Retreat (2024)
- M. Mercado, "Probing Topological Phases of Matter with Quantum Computers," Astronaut Scholarship Foundation Technical Conference (2024)
- M. Mercado and S. Haas, "Stabilizing Topological Phases of Matter on Present-Day Quantum Computers," talk at Southern California Conferences for Undergraduate Research (SCCUR) (2023)
- M. Mercado, "Probing Topological Quantum Matter," invited talk at Bryn Mawr College (2023)
  - **Invited speaker at Bryn Mawr College Physics Dept. Colloquium**, with attendees from Haverford College and Bryn Mawr Math Dept.
- M. Mercado and S. Haas, "Hierarchy of Surface Modes in Disordered Symmetry Protected Topological Insulators," talk at APS Mid-Atlantic Meeting (2023)
- M. Mercado and S. Haas, "Realization of Stable Topological Matter on a Noisy Quantum Computer," talk at Gulf Coast Undergraduate Research Symposium (GCURS) (2023)
- M. Mercado, Z. Hu, L. Liu, "Many-Body Entanglement via Topological Magnons in Hybrid Quantum Multilayers," 5-minute lightning talk video for MIT Office of Graduate Education (2023)
- M. Mercado, Z. Hu, L. Liu, "Many-Body Entanglement via Topological Magnons in Hybrid Quantum Multilayers," talk at MIT Spintronic Material and Device Group (2023)
- M. Mercado and P. Lammert, "Revised Cluster Expansion Method based on Hilbert Space Geometry and GCEP Software Package Implementation," talk at Center for Nanoscale Science Interdisciplinary Research Group (IRG) (2022)

Poster Presentations

- M. Mercado, Z. Hu, L. Liu, "Many-Body Entanglement via Topological Magnons in Hybrid Quantum Multilayers," virtual poster presentation at MSRP Extension Program Virtual Showcase (2023)
- M. Mercado, Z. Hu, L. Liu, "Many-Body Entanglement via Topological Magnons in Hybrid Quantum Multilayers," poster presentation at MIT Summer Research Program Poster Symposium (2023)
- M. Mercado and S. Haas, "Topological Protection Against Disorder in Chiral Symmetric Matter," Poster presentation at USC Undergraduate Symposium for Scholarly and Creative Work; Physical Sciences, Mathematics & Engineering (2023)

– **Best Overall Presentation Award**

- M. Mercado and P. Lammert, "GCEP: A Geometrical Revision of Cluster Expansion Theory," poster presentation at The Pennsylvania State REU Poster Symposium (2022)

Leadership & Organizing in STEM

American Physical Society (APS)
APS Student Ambassador Oct 2023 - Present

- Appointed as home institution's first APS Student Ambassador to represent student body in the APS community. Scheduled to attend the 2025 APS Annual Leadership Meeting in Washington, D.C.
- Worked to remove barriers towards undergraduate participation at the national level by streamlining new department travel and conference registration funds for undergraduate students
- Promoted undergraduate access to scientific literature by organizing and communicating instructions for obtaining subsidized APS *Physical Review Journals* subscriptions via university funding

USC Physics & Astronomy Mentorship Program for Undergraduates (PAMP)
Director Aug 2023 - Present

- Created new departmental program serving undergraduates pursuing degrees in physics and adjacent fields through facilitating educational resources and formation of mentor/mentee relationships with senior members (graduate students, postdocs, faculty), to build a departmental support system and assist historically underrepresented students in natural sciences to navigate systemic challenges in academia
- PAMP is now a university-funded program with ~45 annual total participants, an undergraduate/graduate student executive board, and actively hosts events with local scientific organizations in southern California

University of Southern California, Department of Physics & Astronomy
Physics & Astronomy Department Climate Committee Aug 2023 - Present

- Contributed to 2024 university funding proposal to expand undergraduate support and professional development opportunities in the USC Physics and Astronomy dept.; assisted in organizing new USC Undergraduate Researcher's Retreat
- Organized department programming and events: established PAMP, volunteered in USC science outreach event with local middle schools during Summer 2024, planned undergraduate physics focus group meetups
- Aiding ongoing effort to modernize course selection and content in USC undergraduate physics classes

Upward Bound: STEM
Undergraduate Panelist July 2022

- Participated in Upward Bound: STEM program as an undergraduate panelist; gave advice to cohort of Upward Bound students from Pennsylvania high schools on topics pertaining to navigating higher education as an under-represented minority and Pell Grant recipient college student, student life, and benefits of enrolling in university and pursuing STEM careers

Research Mentor
USC Condensed Matter Theory Group Present

- Presently mentoring two second-year undergraduate students in academic research projects focused on theoretical condensed matter physics in role usually reserved for graduate student
- Organized weekly lectures to mentees in spring 2024 centered on introductory solid state physics and topics in band topology

Advocacy in Education

Office of Illinois House of Representatives Legislator Mark Walker
Researcher Aug 2019 - Mar 2020

- Compiled research briefs under Rep. Mark Walker (IL 53rd district) for two main areas of research: solutions towards inequality in access to mental health resources in Chicago public schools, and solutions towards Illinois' ongoing social worker shortage
- Theorized and drafted state resolution for increased access to mental health resources in underprivileged IL schools through the use of Screening Brief Interventions and Referral to Treatment (SBIRT), modeled after SBIRT usage in other states