

Karthik Ramanathan

Troesh Postdoctoral Scholar Research Associate in Physics
Caltech, MC 376-17, 1200 E. California Blvd., Pasadena, CA 91125, U.S.A
E-mail: karthikr@caltech.edu, Tel: 773-980-0019, Citizenship: CANADA

Education

- Ph.D. University of Chicago **Oct 2015 – Dec 2020**
Advisor: Paolo Privitera
Thesis: *Particles taking selfies: Investigations into Light Dark Matter using Silicon CCDs*
- SM. (Masters) in Physics, University of Chicago **Oct 2015 – Aug 2016**
Coursework based degree enroute to Ph.D.
- MSc. in Finance, London School of Economics **Sep 2010 – Jun 2011**
- BASc. in Engineering Science, University of Toronto **Sep 2005 – Jun 2010**
Graduated with Honors

Research Experience

- California Institute of Technology **Nov 2020 – Present**
Troesh Postdoctoral Fellow
- P.I. of 2 year NSF PHY awarded proposal (#2209581, \$446,991 total, starting Oct 2022) to build Quantum Capacitance Detectors (effectively qubits) coupled to Silicon substrates to detect meV scale phonon excitations – R&D work towards sub-MeV dark matter searches.
 - Co-PI of 1 year \$100K Schwartz-Reisman private foundation award to collaborate with the Rosenblum group at the Weizmann Institute of Science to develop phonon-mediated qubit detector concept in parallel.
 - P.I. of *QUALIPHIDE* (Quantum Limited Photons In the Dark Experiment) – an experiment designed to search for hidden-photon dark matter between 4.5-8 GHz, using Kinetic Inductance Parametric Amplifiers (KIPAs). Proposed, built, and took data with v1 of the experiment, setting new world leading dark matter limits on the existence of 20-30 ueV mass hidden photons (*publication pending*)
 - Proposing an upgraded v2 experiment to search for post-inflationary axion at 65 ueV mass. *Funding proposal in progress.*
 - Integrating KIPAs into ongoing Caltech R&D for phonon-mediated Microwave Kinetic Inductance Detectors (MKIDs) with a goal of demonstrating sub-eV energy resolution. Developing associated laser calibration scheme for the KIDs and identified current drivers of energy resolution variation (*see Publications*).
 - Working with scientists from Fermilab to deploy 0.6 kg SuperCDMS silicon detectors into a DD neutron beam to measure down to 100 eV_{nr} ionization yield.

University of Chicago, Kavli Institute for Cosmological Physics (KICP). **2015-2020**

Advisor: Paolo Privitera

- Developed an empirical model for determining the ionization yield in Silicon from electron-recoil processes (*see Publications*)
- Investigated models of Dark Matter-electron scattering and used DAMIC at Snolab data to place world-leading interaction constraints for dark matter masses between 0.5-6 MeVc⁻² in certain parameter space (*see Publications*).
- Characterized and implemented “Skipper” technology CCDs at UChicago, allowing for operation with single-electron energy resolution. These CCDs will form the basis of the next generation DAMIC-M experiment.
- Performed low-energy Compton scattering calibration work with a UChicago test detector by exposing setup to gamma-ray sources and characterizing resultant spectra. Identified several theoretically motivated, but heretofore unobserved in the literature, structural features of the energy spectrum (*see Publications section*).
- Used DAMIC Science Run data and a novel methodology developed at UChicago, interpreting dark current in the detector as originating from incident dark matter, to place limits on Hidden-Photons, culminating in PRL paper (*see Publications*).
- Conducted calibration studies of CCD energy linearity and resolution based on LED exposure datasets, with results included in WIMP results publication (*see Publications section*).
- Developed MCNP, and to a lesser extent Geant4, particle simulations to assist in various internal and collaboration analyses.

London School of Economics

2010-2011

Advisor: Jean-Pierre Zigrand

Thesis: *Numerical option pricing under a combined Heston Volatility, Kou Jump, and Cox Intensity framework*

- Researched and constructed a novel quantitative option-pricing model utilizing stochastic volatility and doubly stochastic jump processes to better understand fat-tail “black-swan” events in financial markets.

University of Toronto

Summer 2008 & 2009

P. Lavoie Group, UofT Institute for Aerospace Studies

- Modeled vortex generator and plasma actuator behavior in fluid flows and summarized existing research for incoming postdoc. Assisted in design and simulation of actuators for laboratory use.

Weizmann Institute of Science

Summer 2005

N. Davidson Group

- Algorithmically cleaned up dust and diffraction artifacts in images of phonon excitations and collisions in Bose-Einstein Condensates. Published paper in Institute's summer student publication (*see Non-Peer Rev. section*).

Workshop Participation (Selected)

- Community Study on the Future of Particle Physics (Snowmass 2021) – collaborated with members of the dark matter community and helped write a report detailing the landscape of low mass dark matter detection over the next decade (*see Publications*)
- Attend Caltech Center for Teaching, Learning & Outreach pedagogy journal club, to better learn teaching strategies and improving DEI outcomes in the physics community.
- Universidade Federal do Rio de Janeiro (Sep. 2019) - collaborated with UFRJ scientists, thanks to APS travel grant (*see Awards section*), to research machine learning algorithms for particle track detection.
- New Directions in the Search for Light Dark Matter Particles (Jun. 2019) – collaborated with astroparticle community members in outlining immediate research goals for Light Dark Matter investigations.

Conference Presentations and Talks (Selected)

- Applied Superconductivity (ASC, Oct. 2022) - presented on Kinetic Inductance Detectors and progress towards eV energy thresholds
- International Dark Matter (IDM, Jul. 2022) – presented on Kinetic Inductance Detectors and progress towards eV energy thresholds. Poster presentation on QUALIPHIDE.
- APS April Meeting, NYC, NY (Apr. 2022) - presented on QUALIPHIDE progress
- ASU Quantum Engineered Sensors and Technology Invited Talk (Dec. 2021) - presented on broadband hidden photon experiment and QCD proposal
- Low Temperature Detectors 19 (Jul. 2021) - presented on performance of an array of Kinetic Inductance Detectors
- APS April Virtual Meeting, (Apr. 2021) – presented on silicon ionization work
- APS Virtual Meeting (Apr. 2020) – presented preliminary WIMP constraints from 13 kg-day exposure of the DAMIC at Snolab experiment.
- APS Division of Particles and Fields Meeting, Boston, MA. (Aug. 2019) – presented DM-electron analysis and results using DAMIC at SNOLAB data.
- DAMIC-M Annual Collaboration Meeting (Jul. 2019) – presented on analysis and simulation work undertaken at UChicago.
- APS April Meeting, Denver, CO. (Apr. 2019) – presented on leakage current analyses using DAMIC at SNOLAB data

- APS April Meeting, Columbus, OH. (Apr. 2018) – presented on DAMIC-100 WIMP Search progress & DAMIC-M next generation detector.
- APS Canadian-American-Mexican Graduate Conference, Washington D.C. (Aug. 2017) – presented on Hidden Photon paper.
- TeVPA Conference, Columbus, OH. (Aug. 2017) – presented on Compton Scattering paper.
- SNOLAB Users Symposium (Sep. 2016) – presented on progress towards measurement of single scatter Compton electrons.

Awards, Fellowships, and Honors (Selected)

- NSF PHY Grant #2209581 totaling \$446,991 (2022-2024)
- Schwartz-Reisman Grant totaling \$200,000 (2022-2023)
- Troesh Postdoctoral Prize Fellowship (2020+)
- Enrico Fermi Institute Nathan Sugarman Award (2020)
- Fermilab/UChicago Graduate Student Collaborative Research Award (2019)
- UChicago Yodh Prize for outstanding research in experimental physics (2019)
- APS-SBF Brazil-U.S. Exchange Travel Grant of \$3,000 (2019)
- KICP Research Assistantship (2016, 2017, 2018, 2019)
- University of Toronto (Dean's List 2006, 2009, and 2010)
- RoyalHaskoning Delta Competition €10,000 Top Team Prize (2008)
- Queen Elizabeth II Aiming for the Top Scholarship (2005, 2006)
- Bessie F. Lawrence International Summer Science Institute Scholarship (2005)

Teaching, Outreach and Extracurricular Activities (Selected)

- Caltech Connections mentor through the Kavli Nanoscience Institute. Provide informal mentoring to students from minority serving undergraduate institutions in the Pasadena area, with advice ranging from time management to how to approach academics.
- Ran a series of informal seminars discussing and eventually teaching the basics of superconducting devices (e.g. KIDs) to incoming graduate members of the Caltech Observational Cosmology community.
- Judge for Doris S. Perpall SURF Scientific Speaking Competition at Caltech
- Summer Research Connection mentor – hosted summer students for lab based activities through flagship Caltech outreach program.
- Graduate student mentor – acted as a peer-mentor for incoming graduate students.
- Weekly Interactive Meeting of Particle Physicists (WIMPP) - started a weekly journal club in grad. school focused on discussing Experimental/Phenomenology papers where grad. students give 10-15 min. whiteboard talks.

- Middle School Science Bowl– acted as scorekeeper and reader for the Argonne National Labs hosted regional competition.
- Bright Horizons Discovery Days – participated in a monthly grad-student driven effort to present basic science topics in an interactive and playful manner to children ages 2-5 at a local Chicago preschool/daycare.

Other Research Experience (Selected)

University of Toronto 2010

Advisor: Chi-Guhn Lee

Thesis: *Optimization of Bidding Strategies in Electricity Markets*

- Studied behavior of electricity market auctions where bidders submit non-standard bids. Utilized Monte-Carlo methods in combination with linear programming toolkits to simulate large auctions.

DeltaCompetition 2008

Supervisor: James W. Davis (University of Toronto)

- External student competition/call for papers by Royal Haskoning, a Dutch environmental consulting firm.
- Co-author of prize-winning *Design and Deployment of Aquaponic Grid Communities* paper, which proposed engineering solutions to certain climate change problems affecting Deltaic regions around the world.

Non-Academic Professional Experience (Selected)

Viognier Capital Management 2011-2015

Quantitative Associate

- Was responsible for portfolio of ~\$2M USD invested using custom quantitative algorithms. Investigated new trading strategies and promising research avenues (e.g. validity of genetic algorithms for data mining).

Messier-Dowty Inc. 2008-2009

Systems Engineer

- Designed & programmed an alpha version of a Landing Gear Control Unit simulator for the Sukhoi SJ100 airplane and the Airbus A350 bid.

Publications

- ✓ indicates major contribution

Pending Review

- ✓ K. Ramanathan, N. Klimovich, ... *[6 authors omitted]*. Wideband Direct Detection Constraints on Hidden Photon Dark Matter with the QUALIPHIDE Experiment. Submitted to Physical Review Letters (Oct 2022) arXiv:2209.03419
 - Demonstrated a first probing of the hidden photon kinetic mixing parameter to just above 10^{-12} for hidden photon dark matter masses between 20-30 ueV.

Peer Reviewed

- D. Norcini et al. *[42 authors omitted]*. Precision measurement of Compton scattering in silicon with a skipper CCD for dark matter detection. Physical Review D 106, 092001 (2022) (DOI: 10.1103/PhysRevD.106.092001)
 - Re-measurement of Compton steps with much improved resolution. Contributed to initial experimental setup.
- ✓ K. Ramanathan, T. Aralis, ... *[5 authors omitted]*. Identifying Drivers of Energy Resolution Variation in multi-KID phonon-mediated Detectors. Journal of Low Temperature Physics (2022) (DOI:10.1007/s10909-022-02753-5)
 - Analyzed responsivity of an array of KID detectors, identified and modeled a large variation in energy resolution between detectors and traced its origin to the presence of box modes within the device housing.
- ✓ O. Wen, ... K. Ramanathan, ... *[5 authors omitted]*. Performance of a Phonon-Mediated Detector using KIDs Optimized for Sub-GeV Dark Matter. Journal of Low Temperature Physics (2022) (DOI:10.1007/s10909-022-02764-2)
 - Reported on performance of a gram-scale single KID detector. Contributed to device operation, data-taking, and analysis pipeline.
- A. Aguilar-Arevalo et al. *[alphabetical listing, 33 authors omitted]*. Characterization of the background spectrum in DAMIC at SNOLAB. Physical Review D 105, 062003 (DOI: 10.1103/PhysRevD.105.062003)
 - Paper provided an in-depth background model for the DAMIC experiment.
- R. Saldanha et al. *[12 authors omitted]*. Cosmogenic Activation of Silicon. Physical Review D 102, 102006 (2020) (DOI: 10.1103/PhysRevD.102.102006)
 - Constrained production of ^3H , ^7Be , and ^{22}Na by irradiating a silicon CCD with a neutron beam, mimicking cosmogenic activation. Assisted in image processing for CCD data.
- ✓ K. Ramanathan, N. Kurinsky. Ionization Yield in Silicon for eV-scale Electron-Recoil Processes. Physical Review D 102, 063026 (2020) (DOI: 10.1103/PhysRevD.102.063026)

- Investigated models of charge splitting in silicon detectors, with an eye to providing a probabilistic prescription for translating deposited energy in electron-recoil processes into ionization charge.
- A. Aguilar-Arevalo et al. [*alphabetical listing, 31 authors omitted*]. Results on Low-Mass Weakly Interacting Massive Particles from an 11 kg-day Target Exposure of DAMIC at SNOLAB. *Phys. Rev. Lett.* **125**, 241803 (DOI:10.1103/PhysRevLett.125.241803)
 - Exclusion limits on <10 GeV WIMPs. Member of the analysis group, worked on likelihood based event and depth reconstruction code.
- A. Aguilar-Arevalo et al. [*alphabetical listing, 30 authors omitted*]. Measurement of the bulk radioactive contamination of detector-grade silicon with DAMIC at SNOLAB. *Journal of Instrumentation* **16**, P06019 (DOI:10.1088/1748-0221/16/06/P06019)
 - Constrained radioactive contamination within silicon CCDs.
- ✓ A. Aguilar-Arevalo, ... K. Ramanathan, ... [*alphabetical listing, 32 authors omitted*]. Constraints on Light Dark Matter Particles Interacting with Electrons from DAMIC at SNOLAB. *Phys. Rev. Lett.* **123** (2019) (DOI: 10.1103/PhysRevLett.123.181802)
 - Exclusion limits on DM-electron interactions. Performed majority of analysis and wrote most of the paper.
- ✓ K. Ramanathan, A. Kavner, ... [*9 authors omitted*]. Measurement of low energy ionization signals from Compton scattering in a charge-coupled device dark matter detector. *Physical Review D* **96**, 042002 (2017) (DOI: 10.1103/PhysRevD.96.042002)
 - First measurement of Compton step features. Conducted majority of the experimental work, majority of the analysis and paper.
- ✓ A. Aguilar-Arevalo, ... K. Ramanathan, ... [*alphabetical listing, 37 authors omitted*]. First Direct-Detection Constraints on eV-Scale Hidden-Photon Dark Matter with DAMIC at SNOLAB. *Phys. Rev. Lett.* **118** (2017) (DOI: 10.1103/PhysRevLett.118.141803)
 - Exclusion limits on hidden photon DM. Considered as first author within collaboration, performed majority of analysis
- A. Aguilar-Arevalo, ... K. Ramanathan, ... [*alphabetical listing, 36 authors omitted*]. Search for low-mass WIMPs in a 0.6 kg day exposure of the DAMIC experiment at SNOLAB. *Phys. Rev. D* **94** (2016) (DOI: 10.1103/PhysRevD.94.082006)
 - Exclusion limits on low mass WIMPs. Conducted analysis for Section IV. A. *Energy Response of a DAMIC CCD*

Technical Reports

- ✓ R. Essig et al. [*5 authors omitted*]. Snowmass2021 Cosmic Frontier: The landscape of low-threshold dark matter direct detection in the next decade. (2022) arXiv:2203.08297 [hep-ph]
 - Summarizes the science case for low mass DM searches and details future approaches. Contributed extensively to outlining search modalities at the meV to eV scale.
- D. Baxter et al. [*50 authors omitted*]. Snowmass2021 Cosmic Frontier: Calibrations and backgrounds for dark matter direct detection. (2022) arXiv:2203.08297 [hep-ex]
 - White paper on calibrations and background requirements for the next generation of DM detectors. Helped outline calibration strategies (*Sections 2.1 & 2.2*) for ionization detectors at the <100 eV scale.
- D. Baxter et al. [*alphabetical listing, 12 authors omitted*]. Coherent Elastic Neutrino-Nucleus Scattering at the European Spallation Source. arXiv:1911.00762 [physics.ins-det]
 - Contributed material and figures to Section *III. B. Low-background CCD arrays with single-electron threshold*

Proposals

- P. Mausekopf et al. Center for Quantum Sensing in Particle Physics and Cosmology at ASU (2022) (for NSF Physics Frontier Center program solicitation) – unsuccessful
 - Contributed to outlining low-mass DM efforts in proposed center
- ✓ S. Golwala, K. Ramanathan, S. Rosenblum. Quantum Detectors for Astroparticle Physics (2022) (for Schwartz-Reisman Collaborative Science Program) - successful
 - Awarded \$200K to be split equally between Caltech and Weizmann Institute
- ✓ K. Ramanathan, S. Golwala. Quantum Capacitance Detectors with meV Resolution for Astroparticle Physics (2021) (for NSF Program Solicitation 21-593) – successful
 - Awarded \$450K over 2 years for phonon-QCD R&D

Non-peer reviewed

- Kovac, J., Ramanathan, K., Pugatch, R., and Davidson, N. Anti-Polar Absorption Symmetry in Bose-Einstein Condensates. *Weizmann Institute of Science - International Summer Science Institute Journal*. (2005)