Rufus Boyack

Personal Information

Citizenship: New Zealand
Email: rufus.boyack@dartmouth.edu
Office: Wilder 246

Research Interests

My research interests are focused on transport signatures and emergent phenomena in superfluids and superconductors. In addition, I am interested in critical phenomena in spin liquids.

Education

University of Chicago, Chicago, IL, USA

Ph.D., Physics, 2017

- Thesis title: *Establishing a consistent theory of transport in strongly correlated matter*
- Supervisor: Prof. Kathryn Levin

M.S., Physics, 2013

Victoria University of Wellington, Wellington, NZ

M.Sc. (Distinction), Physics, 2011

- Thesis title: *The theory of the hydrogen molecule ion, scalar beams, and scattering by spheroids*
- Supervisor: Prof. John Lekner

Grad. Dipl. Sci., Mathematics, 2011

B.Sc. Hons. (First class), Physics, 2010

B.Sc., Mathematics and Physics, 2009

Hutt Valley High School, Lower Hutt, NZ

NCEA Level 3, 2005

NCEA Level 2, 2004

NCEA Level 1, 2003

Professional appointments

Dartmouth College, Hanover, NH, USA

Assistant Professor 2022 –

Postdoctoral appointments

Université de Montréal, Montréal, QC, Canada

Postdoctoral scholar, 2020-2022

- Supervisor: Prof. William Witczak-Krempa

University of Alberta, Edmonton, AB, Canada

Theoretical Physics Institute fellow, 2017-2020

- Supervisors: Prof. Frank Marsiglio and Prof. Joseph Maciejko

Research Experience

Postdoctoral fellow 2020-2022
Physics department, Université de Montréal
Supervisor: Prof. William Witczak-Krempa
Achievements:
(i) Studied monopole scaling dimensions in transitions from a Dirac spin liquid to two chiral spin liquids.
(ii) Investigated thermal Hall conductivity response in the pseudogap phase of the cuprates.

Postdoctoral fellow 2017-2020
Theoretical Physics Institute, University of Alberta
Supervisors: Prof. Joseph Maciejko and Prof. Frank Marsiglio
Achievements:
(i) Studied deconfined quantum critical spin liquids using large-N and ϵ-expansion methods.
(ii) Derived a functional-integral-based formalism for Eliashberg theory and its Gaussian extension.
(iii) Investigated signatures of the Hall conductivity in the pseudogap phase of the cuprates.

Research Assistant 2014-2017
James Franck Institute, University of Chicago
Supervisor: Prof. Kathryn Levin
Achievements:
(i) Derived the complete expression for the superfluid density of the Fulde-Ferrell superfluid.
(ii) Formulated a general diagrammatic method for studying gauge-invariant electromagnetic response.
(iii) Proved how to ensure thermodynamic sum rule compatibility for fermionic superfluids.

Research Assistant 2010-2011
Physics department, Victoria University of Wellington
Supervisor: Prof. John Lekner
Achievements:
(i) Derived a transcendental equation to determine the eigenvalue in the oblate spheroidal wave equation.
(ii) Formulated a partial wave scattering theory of spheroids in analogue with the spherical case.

Summer Research Assistant 2009
Physics department, Victoria University of Wellington
Supervisor: Prof. Eric Le Ru
Achievements: Implemented a numerical method for studying EM scattering by spheroidal nanoparticles.

Summer Research Assistant 2009
Physics department, Victoria University of Wellington
Supervisor: Prof. Eric Le Ru
Achievements: Implemented a numerical approach for studying electromagnetic scattering of arbitrary shaped spheroidal nanoparticles.

Publications

Journal articles

38. Binet's second formula, Hermite's generalization, and two related identities [Rufus Boyack] – Accepted – Open Mathematics (2023).

37. Electrical conductivity and Nuclear magnetic resonance relaxation rate of Eliashberg superconductors in the weak-coupling limit [Rufus Boyack, Sepideh Mirabi, Frank Marsiglio] Commun. Phys. **6**, 54 (2023).

36. The bound-state solutions of the one-dimensional pseudoharmonic oscillator [Rufus Boyack, Asadullah Bhuiyan, Aneca Su, Frank Marsiglio] J. Math. Chem. **61**, 242 (2023).

35. Anomalous Dimensions of Monopole Operators at the Transitions between Dirac and Topological Spin Liquids [Éric Dupuis, Rufus Boyack, and William Witczak-Krempa] Phys. Rev. X **12**, 031012 (2022).

34. Heat-bath approach to anomalous thermal transport: Effects of inelastic scattering [Zhiqiang Wang, Rufus Boyack, and K. Levin] Phys. Rev. B **105**, 134302 (2022).

33. Triangular Pair Density Wave in Confined Superfluid ^{3}He [Pramodh Senarath Yapa, Rufus Boyack, and Joseph Maciejko] Phys. Rev. Lett. **128**, 015301 (2022).

32. Unified approach to electrical and thermal transport in high-T_c superconductors [Rufus Boyack, Zhiqiang Wang, Qijin Chen, and Kathryn Levin] Phys. Rev. B **104**, 064508 (2021).

31. Functional-integral approach to Gaussian fluctuations in Eliashberg theory [Mason Protter, Rufus Boyack, and Frank Marsiglio] Phys. Rev. B **104**, 014513 (2021).

30. Summation of certain trigonometric series with logarithmic coefficients [Rufus Boyack] J. Analysis **30**, 119 (2022).

29. Quantum phase transitions in Dirac fermion systems [Rufus Boyack, Hennadii Yerzhakov, and Joseph Maciejko] Eur. Phys. J. Spec. Top. **230**, 979 (2021).

28. Critical exponents for the valence-bond-solid transition in lattice quantum electrodynamics [Rufus Boyack, Joseph Maciejko] Proceedings of the 11th International Symposium on Quantum Theory and Symmetries (QTS-XI), edited by M. B. Paranjape et al. (Centre de Recherches Mathématiques CRM Series in Mathematical Physics, Springer, 2021), pp. 337-345.

27. The bound-state solutions of the one-dimensional hydrogen atom [Rufus Boyack, Frank Marsiglio] Am. J. Phys **89**, 418 (2021).

26. Thermodynamics of Eliashberg theory in the weak-coupling limit [Sepideh Mirabi, Rufus Boyack, and Frank Marsiglio] Phys. Rev. B **102**, 214505 (2020).

25. Critical properties of the valence-bond-solid transition in lattice quantum electrodynamics [Nikolai Zerf, Rufus Boyack, Peter Marquard, John A. Gracey, and Joseph Maciejko] Phys. Rev. D **101**, 094505 (2020).

24. Electromagnetic response of superconductors in the presence of multiple collective modes [Rufus Boyack, Pedro L. e S. Lopes] Phys. Rev. B **101**, 094509 (2020).

23. Eliashberg theory in the weak-coupling limit: Results on the real frequency axis [Sepideh Mirabi, Rufus Boyack, Frank Marsiglio] Phys. Rev. B **101**, 064506 (2020).

22. Stabilized Pair Density Wave via Nanoscale Confinement of Superfluid ^{3}He [A.J. Shook, V. Vadakumbatt, P. Senarath Yapa, C. Doolin, R. Boyack, P.H. Kim, G.G. Popowich, F. Souris, H. Christani, J. Maciejko, J.P. Davis] Phys. Rev. Lett. 124, 015301 (2020).

21. Critical properties of the Néel-to-algebraic spin liquid transition [Nikolai Zerf, Rufus Boyack, Peter Marquard, John A. Gracey, Joseph Maciejko] Phys. Rev. B 100, 235130 (2019).

20. Deconfined criticality in the QED_3 Gross-Neveu-Yukawa model: The $1/N$ expansion revisited [Rufus Boyack, Ahmed Rayyan, and Joseph Maciejko] Phys. Rev. B **99**, 195135 (2019).

19. Combined effects of pairing fluctuations and a pseudogap in the cuprate Hall coefficient [Rufus Boyack, Xiaoyu Wang, Qijin Chen, and Kathryn Levin] Phys. Rev. B **99**, 134504 (2019).

18. Restoring gauge invariance in conventional fluctuation corrections to a superconductor [Rufus Boyack] Phys. Rev. B **98**, 184504 (2018).

17. Critical behaviour of the QED_3-Gross-Neveu-Yukawa model at four loops [Nikolai Zerf, Peter Marquard, Rufus Boyack, Joseph Maciejko] Phys. Rev. B **98**, 165125 (2018).

16. Transition between algebraic and $\mathbb{Z}_2$ quantum spin liquids at large N [Rufus Boyack, Chien-Hung Lin, Nikolai Zerf, Ahmed Rayyan, Joseph Maciejko] Phys. Rev. B **98**, 035137 (2018).

15. Cuprate diamagnetism in the presence of a pseudogap: Beyond the standard fluctuation formalism [Rufus Boyack, Qijin Chen, Andrey A. Varlamov, Kathryn Levin] Phys. Rev. B **97**, 064503 (2018).

14. Collective mode contributions to the Meissner effect: Fulde-Ferrell and pair-density wave superfluids [Rufus Boyack, Chien-Te Wu, Brandon M. Anderson, Kathryn Levin] Phys. Rev. B **95**, 214501 (2017).

13. Gauge-invariant theories of linear response for strongly correlated superconductors [Rufus Boyack, Brandon M. Anderson, Chien-Te Wu, Kathryn Levin] Phys. Rev. B **94**, 094508 (2016).

12. Two-dimensional spin-imbalanced Fermi gases at nonzero temperature: Phase separation of a noncondensate [Chien-Te Wu, Rufus Boyack, Kathryn Levin] Phys. Rev. A **94**, 033604 (2016).

11. Going beyond the BCS level in the superfluid path integral: A consistent treatment of electrodynamics and thermodynamics [Brandon M. Anderson, Rufus Boyack, Chien-Te Wu, Kathryn Levin] Phys. Rev. B **93**, 180504(R) (2016).

10. Quasicondensation in Two-Dimensional Fermi Gases [Chien-Te Wu, Brandon M. Anderson, Rufus Boyack, Kathryn Levin] Phys. Rev. Lett. **115**, 240401 (2015).

9. Topological effects on transition temperatures and response functions in three-dimensional Fermi gases [Brandon M. Anderson, Chien-Te Wu, Rufus Boyack, Kathryn Levin] Phys. Rev. B **92**, 134523 (2015).

8. Signatures of pairing and spin-orbit coupling in correlation functions of Fermi gases [Chien-Te Wu, Brandon M. Anderson, Rufus Boyack, Kathryn Levin] Phys. Rev. B **91**, 220504(R) (2015).

7. Exact correlation functions in the cuprate pseudogap phase: Combined effects of charge order and pairing [Rufus Boyack, Chien-Te Wu, Peter Scherpelz, Kathryn Levin] Phys. Rev. B **90**, 220513(R) (2014).

6. Shear viscosity and imperfect fluidity in bosonic and fermionic superfluids [Rufus Boyack, Hao Guo, Kathryn Levin] Phys. Rev. B **90**, 214501 (2014).

5. Confluent Heun functions and separation of variables in spheroidal coordinates [Rufus Boyack, John Lekner] J. Math. Phys **52**, 073517 (2011).

4. Non-existence of separable spheroidal beams [Rufus Boyack, John Lekner] J. Opt. **13**, 085701 (2011).

3. Axisymmetric scattering of scalar waves by spheroids [John Lekner, Rufus Boyack] J. Acoust. Soc. Am. **129**, 3465 (2011).

2. Constraints on spheroidal beam wavefunctions [John Lekner, Rufus Boyack] Opt. Lett. **35**, 3652 (2010).

1. Investigation of particle shape and size effects in SERS using T-matrix calculations [Eric C. Le Ru, Rufus Boyack] Phys. Chem. Chem. Phys. **11**, 7398 (2009).

Book reviews

1. Electrostatics of conducting cylinders and spheres [Rufus Boyack], Contemporary Physics 1-2, (2022).

Honours and Awards

Student Awards

University of Chicago:
- Physics department distinguished service award 2016
- Physical sciences teaching prize (Top teaching assistant in the physical sciences division) 2015
- Sachs fellowship 2012

Victoria University of Wellington:
- Victoria Masters by thesis scholarship 2010
- Dan F. Jones scholarship in Science 2009
- Victoria Graduate Award 2009
- Florance award in Physics (Top 3rd year Physics student) 2008
- Noel Ryder prize in Physics (Top 2nd year Physics student) 2007
- Macmorran prize in Mathematics (Top 2nd year Mathematics student) 2007

Hutt Valley High School:
- Top 7th form physics student 2005
- Calculus scholarship 2005

Presentations

Invited talks

- Quantum materials Canada 2.0; Jouvence, Québec, Canada: "Anomalous dimensions of monopole operators at the transitions between Dirac and topological spin liquids" 26 May 2022
- Dartmouth College Colloquium; Virtual: "Electrical and Thermal transport signatures of the pseudogap phase in high-T_c superconductors" 2 March 2022
- Dartmouth College Condensed Matter seminar; Virtual: "Electromagnetic Response of Superconductors in the Presence of Multiple Collective Modes" 1 March 2022
- Centre de recherches mathématiques (CRM) Séminaire Physique Mathématique, Université de Montréal: "Critical properties of quantum spin liquid phase transitions" 14 September 2021
- Regroupement Québécois sur les matériaux de pointe (RQMP) E-Séminaires, Université de Montréal: "Amplitude-mode contribution to the Meissner effect in Fulde-Ferrell superfluids" 5 October 2020
- Quantum fluids and solids (QFS) 2019; Edmonton, Alberta, Canada: "Diamagnetism and Hall conductivity in the cuprates" 12 August 2019
- Theoretical Physics Institute (TPI) seminar, University of Alberta: "Collective mode contributions to the Meissner effect in Fulde-Ferrell and pair-density wave superfluids" 9 November 2017
- Banff International Research Station (BIRS) – BIRS Workshop17w2694: Contemporary Topics in Mathematical Physics; Banff, Alberta, Canada: "Importance of amplitude collective modes in the path integral approach to Fermi superfluids" 29 October 2017

March meeting talks

- APS March meeting; Las Vegas, Nevada, USA: "Electrical conductivity of Eliashberg theory in the weak-coupling limit" 8 March 2023
- APS March meeting; Chicago, Illinois, USA: "Anomalous dimensions of monopole operators at the transitions between Dirac and topological spin liquids" 15 March 2022
- APS March meeting; Virtual: "The effect of the pseudogap on thermomagnetic transport in cuprates" 18 March 2021
- APS March meeting; Boston, Massachusetts, USA: "Deconfined criticality in the QED_3 Gross Neveu Yukawa model" 7 March 2019
- APS March meeting; Los Angeles, California, USA: "Cuprate diamagnetism in the strong pairing fluctuation formalism" 9 March 2018
- APS March meeting; New Orleans, Louisiana, USA: "Collective mode contributions to the superfluid density in Fulde-Ferrell superfluids" 15 March 2017
- APS March meeting; Baltimore, Maryland, USA: "Gauge invariant theories of strongly correlated Fermi superfluids" 17 March 2016
- APS March meeting; San Antonio, Texas, USA: "Shear viscosity to entropy density ratios: (im)perfect fluidity in Bosonic and Fermionic superfluids" 2 March 2015

Student talks

- UChicago Society of Physics (SPS): "Classical Physics as Geometry: Geometrodynamics" 20 April 2015
- UChicago Society of Physics (SPS): "Interpretations of Quantum Mechanics: Ensemble vs Individual Interpretations" 14 April 2014

Student supervision

Masters students

- Simon Martin, Université de Montréal: "Conductivité pour des fermions de Dirac prés d'un point critique quantique" (2021)
- Mason Protter, University of Alberta: "Particle-hole fluctuations in superconductors" (2019)
- Sepideh Mirabi, University of Alberta: "Weak-coupling Eliashberg theory" (2019)

Teaching Experience

Dartmouth College

- P22 Mathematical methods of Physics 2023

University of Alberta

Guest lecturer:

- Graduate physics Journal Club (10 lectures): Fluctuation theory of superconductors 2018
- PHYS 699 Advanced statistical mechanics (2 lectures): Chern-Simons theory 2018
- Graduate physics Journal Club (3 lectures): Topological aspects of field theory 2019

University of Chicago

Teaching assistant:

- PHYS 236 Solid State Physics 2013
- PHYS 234 Quantum Mechanics 1 2013 & 2016
- PHYS 227 Electromagnetism 2 2014 & 2015
- PHYS 225 Electromagnetism 1 2014
- PHYS 197 Statistical Mechanics 2012, 2013 & 2014
- PHYS 133 Waves & Optics 2012 & 2013
- PHYS 132 Electromagnetism 2012 & 2013
- PHYS 131 Mechanics 2011 & 2013

Victoria University of Wellington

Lab demonstrator:

- PHYS 235 Analogue Electronics 2009 & 2010
- PHYS 234 Digital Electronics 2009

Professional activities

Referee service

Annals of physics, Nature communications, Physical Review Letters, Physical Review A, Physical Review B, Quarterly Journal of Mechanics and Applied Mathematics, Scientific Reports, Substantia.

Software Skills

- Maple
- Mathematica
- Latex, LyX
- Julia