Condensed Matter Theory

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Yuan-Ming Lu

William Putikka

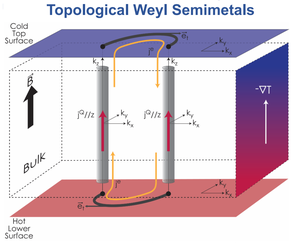
Brian Skinner

Mohit Randeria

Nandini Trivedi

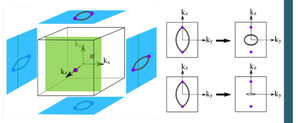
Topological Dirac and Weyl Semimetals (NSF MRSEC)

Fermi-Arc Mediated Transport in Topological Weyl Semimetals



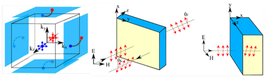
L. Huang, T. McCormick, M. Ochi, Z. Zhao, M. Suzuki, R. Arita, Y. Wu, D. Mou, M. Cao, J. Yan, N. Trivedi and A. Kaminski, Nature Materials **15**, 1155 (2016)
T. McCormick, R. McKay and N. Trivedi, Phys. Rev B **96** 235116 (2017)
T. M. McCormick, S. Watzman, J. P. Heremans, N. Trivedi arXiv:1703.04606

Topological Protection of Fermi Arcs in Dirac Semimetals



M. Kargarian, M. Randeria and Y.-M. Lu, PNAS 113, 8648 (2016)

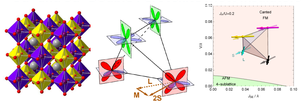
Faraday and Kerr Rotation of Weyl Semimetals



Mehdi Kargarian, Mohit Randeria and Nandini Trivedi, Scientific Reports **5**, 12683 (2015)

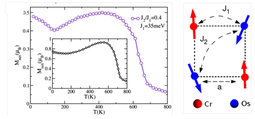
Magnetism and Spin-orbit Coupling in Correlated Materials (NSF MRSEC)

Intertwined orbital and magnetic order in $5d^1$ and $5d^2$ Double Perovskite Mott Insulators



W. Zhang, C. Svoboda, M. Randeria, N. Trivedi (unpublished)

High T_C ferrimagnetism in Sr_2CrOsO_6



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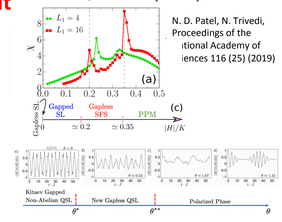
Phys. Rev. Lett. **110**, 087203 (2013)

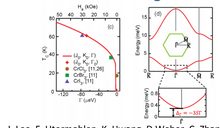
Quantum Spin Liquids



N. D. Patel, N. Trivedi, Proceedings of the National Academy of Sciences 116 (25) (2019)

D. Ronquillo, A. Vengal, N. Trivedi
Phys. Rev. B 99, 140413(R) (2019)

2D Ferromagnetism



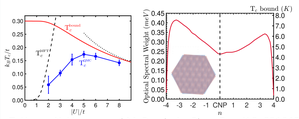
I. Lee, F. Utermohlen, K. Hwang, D.Weber, C. Zhang, J. van Tol, J. Goldberger, N. Trivedi, and P.C. Hammel
Phys. Rev. Lett. 124, 017201 (2020)

Strongly Correlated Superconductors (SC)

Upper Bounds on T_C in 2D

$T_c \le \frac{1}{4} E_F$ For parabolic dispersion

Magic-Angle Twisted Bilayer Graphene



T. Hazra, N. Verma, and M. Randeria; Phys. Rev. X 9, 031049 (2019)

BCS-BEC Crossover

Ultracold atoms:
Ann. Rev. Cond. Mat. Phys. **5**. 209 (2014)
PRL **109**, 135301 (2012)
PNAS **108**, 51 (2011)
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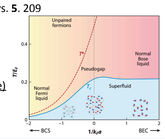
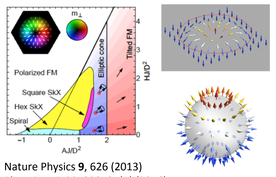
Multi-band SC in Fe(Se,Te) (with A. Kanigel):
Science Advances **3**, e1602372 (2017)



Skyrmions in Chiral Magnets



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SC-Insulator Transition

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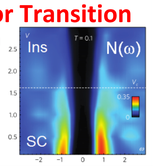
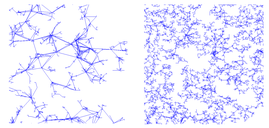


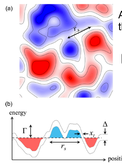
Random Networks

A description of electron transport in disordered environments



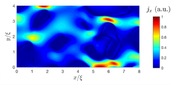
Active sites for transport at low temperature (left) and higher temperature (right) in the localized phase.

[Chen and Skinner, Phys. Rev. B 94, 085146 (2016)]

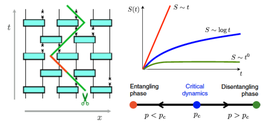


A smooth random potential (left) has the effect of focusing electric current along filamentary paths (below)

[Nandi, Skinner, et al, Phys. Rev. B 98, 214203 (2018)]

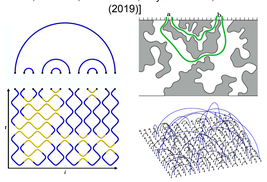


A description of the dynamics of quantum entanglement



A sequence of quantum interactions can be modeled as "circuit" in space and time. The entanglement in the system is described via the statistics of cuts in the circuit.

[Skinner, Ruhman, and Nahum, Phys. Rev. X 9, 031009 (2019)]



[Skinner and Nahum, arXiv:1911.11169 (2019)]

Disordered Systems

Quantum Hall transitions and supersymmetry

Bondesan, **Gruzberg**, Jacobsen, Obuse, Saleur, PRL (2012)
Bettelheim, **Gruzberg**, Ludwig, PRB (2012)
Obuse, **Gruzberg**, Evers, PRL (2012)
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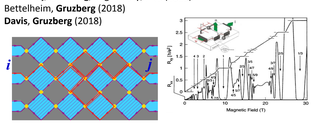
Bettelheim, **Gruzberg** (2018)
Davis, **Gruzberg** (2018)



Disordered quantum wires

Schnyder, Mudry, **Gruzberg**, Nucl. Phys B (2009)
Falco, Fedorenko, **Gruzberg**, Europhys. Lett. (2017)
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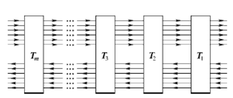
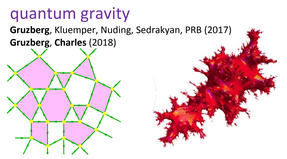


Geometric disorder and quantum gravity

Gruzberg, Kluemper, Nuding, Sedrakyan, PRB (2017)
Gruzberg, **Charles** (2018)



Multifractal wave functions at Anderson transitions

Gruzberg, Ludwig, Mirlin, Zirnbauer, PRL (2011)
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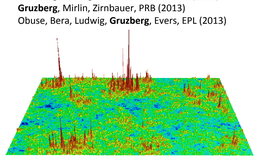


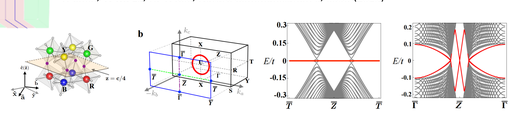
Topological Insulators (TIs) and Semimetals

TIs and Symmetry Protected Topological (SPT) phases

Y.-M. Lu, A. Vishwanath, Phys. Rev. B 86, 125119 (2012)
X. Chen, **Y.-M. Lu**, A. Vishwanath, Nature Communications 5, 3507 (2014)
F. Lu, B. Shi, Y.-M. Lu, New J. Phys. 19, 073002 (2017)
J. Wu, T.-L. Ho, Y.-M. Lu, arXiv 1703.04776

Topological crystalline metals

Y. Chen, **Y.-M. Lu**, H.-Y. Kee, Nature Communication 6, 6593 (2015)

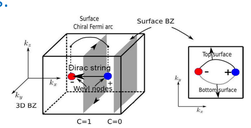


Topological Weyl/Dirac semimetals:

K.-Y. Yang, **Y.-M. Lu**, Y. Ran, Phys. Rev. B 84, 075129 (2011)
C. Y. Cho, J. Bardarson, **Y.-M. Lu**, J. E. Moore, Phys. Rev. B 86, 214514 (2012) *Editor's suggestion*
M. Kargarian, M. Randeria, Y.-M. Lu, PNAS 113, 8648 (2016)

Topological superconductivity

Y.-M. Lu, T. Xiang, D.-H. Lee, Nature Physics 10, 634 (2014)



Highly-Entangled Quantum Matter

Quantum Spin Liquids

R. Schaffer, K.-H. Lee, **Y.-M. Lu**, Y.-B. Kim, PRL 114, 116803 (2015)
M. Zaletel, Z. Zhu, **Y.-M. Lu**, A. Vishwanath, S. R. White, PRL 116, 197203 (2016)
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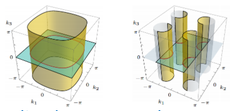
B. Huang, Y.-B. Kim, **Y.-M. Lu**, PRB 95, 054404 (2017)



Fractionalized quantum phases

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T. H. Hsieh, **Y.-M. Lu**, A. Ludwig, Sci. Adv. (2017)
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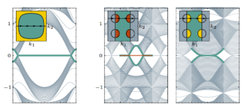
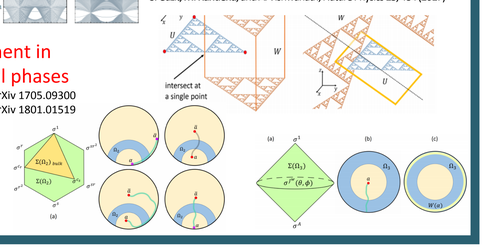
S. Gazit, **M. Randeria**, and A. Vishwanath; Nature Physics 13, 484 (2017)



Entanglement in topological phases

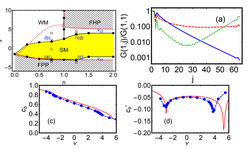
B. Shi, Y.-M. Lu, arXiv 1705.09300
B. Shi, Y.-M. Lu, arXiv 1801.01519



Theory of Cold Atoms

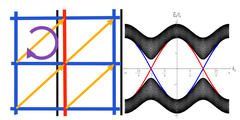
Majorana Fermions

Yin, Ho & Cui, arXiv:1711.08765



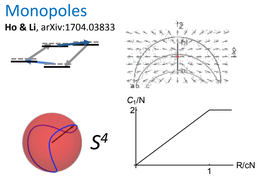
Quantum Spin Hall Effect

Wu, Ho & Lu, arXiv:1703.04776



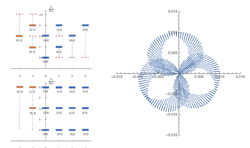
Monopoles

Ho & Li, arXiv:1704.03833



Quantum Hall Effect in Light

Ho & Chen, in preparation



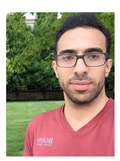
Graduate Students

N. Charles

S. Feng

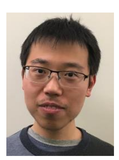
X. Feng

T. Hazra


M. Karaki

C. Li

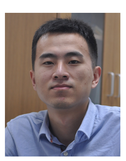
D. Ronquillo

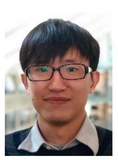

B. Shi

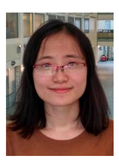
J. Szabo

F. Utermohlen

N. Verma


C. Wang


P.-K. Wu


W. Zhang

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Z. Addison

O. Ávalos-Ovando

A. Rasmussen

W. Zheng