

Ultra Quantum Matter

Simons Collaboration Kickoff Meeting

Ashvin Vishwanath
Harvard University

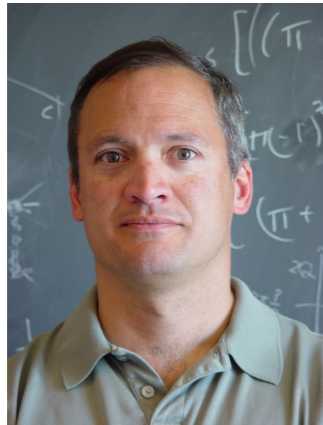
Simons Collaboration on Ultra Quantum Matter

What is “Ultra-Quantum”?

Why does it matter?

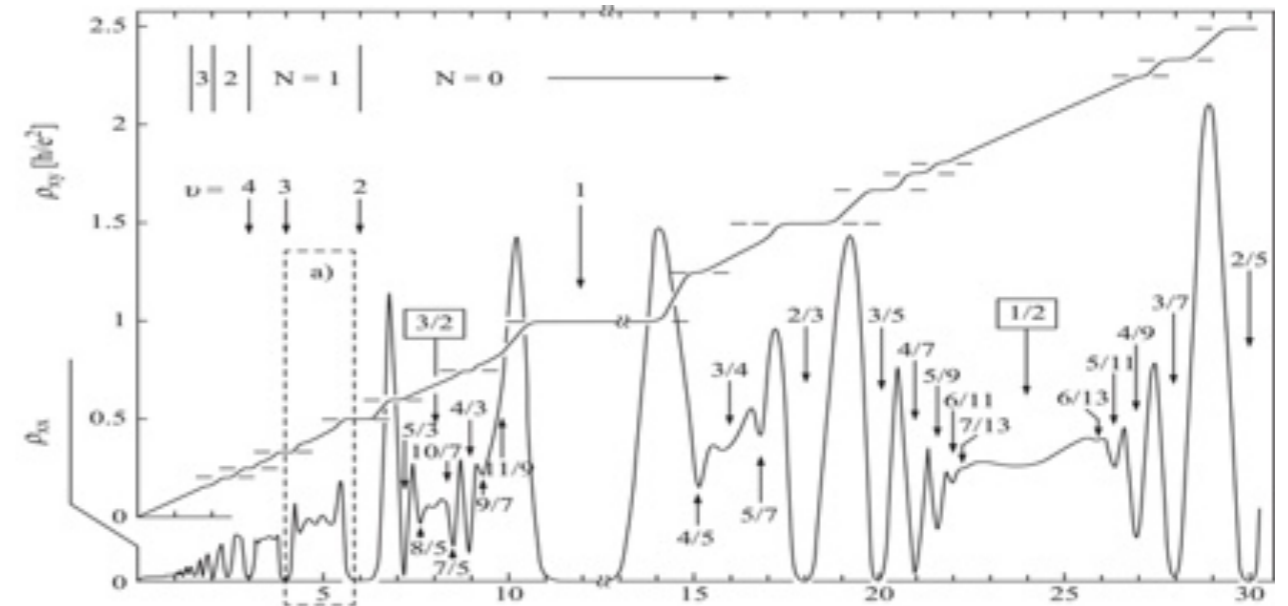
Why now ?

Highly Entangled Quantum Matter

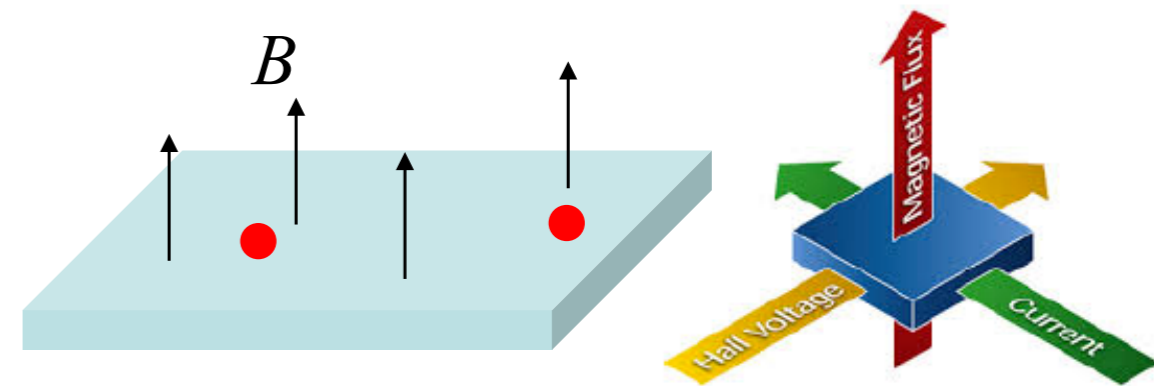


Leon Balents

“Ultra” Quantum Matter



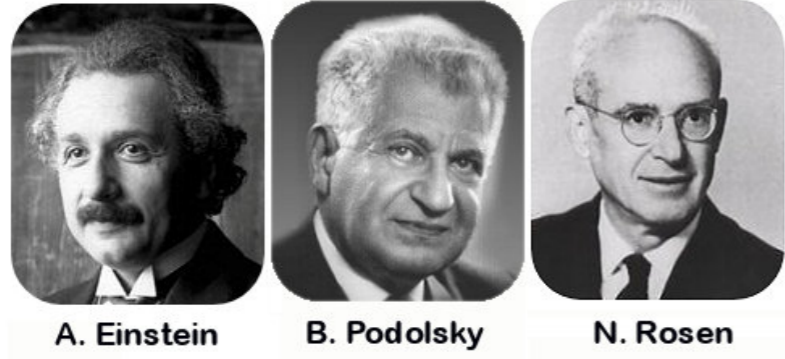
VS.



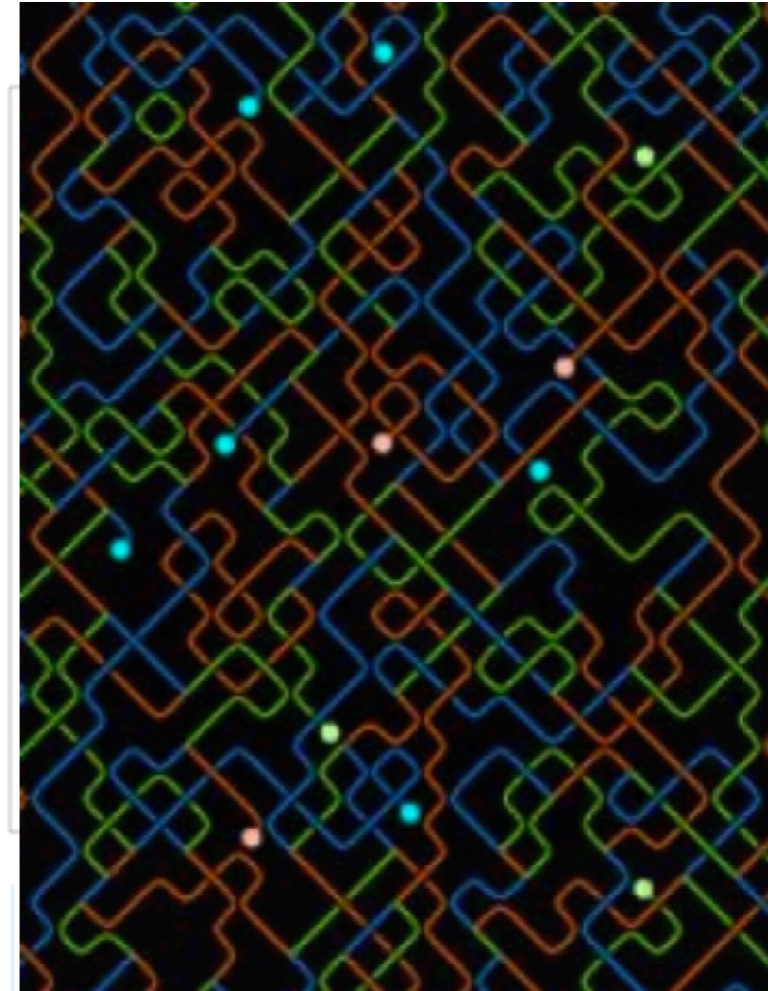
Solid - Classical order parameter
 $\rho(\mathbf{q})$ - density

Quantum Hall States:
 Highly entangled quantum states

Non-local Quantum Entanglement



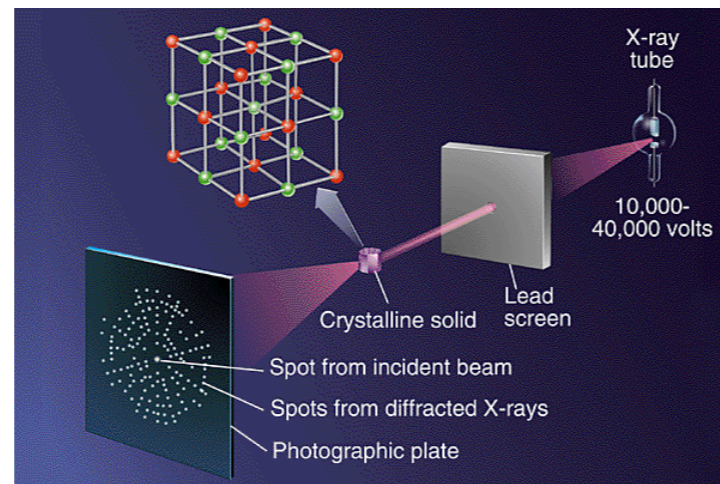
Entanglement - EPR Pair



Quantum Hall state
 $\nu > 0$

Classical orders vs Ultra-quantum Matter

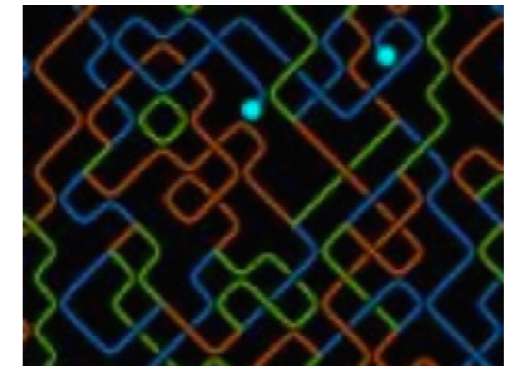
- Crystals - classify all patterns of symmetry breaking (230 space groups)



- Probe - using X-ray scattering

- *All 230* space groups realized in nature.

- Classify gapped/gapless highly entangled quantum ground states.



- Novel probes needed

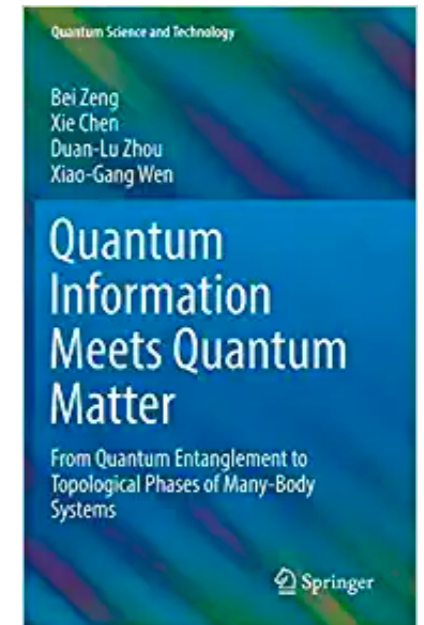
- Realize or *engineer* in synthetic systems.

Why - ultra quantum matter?

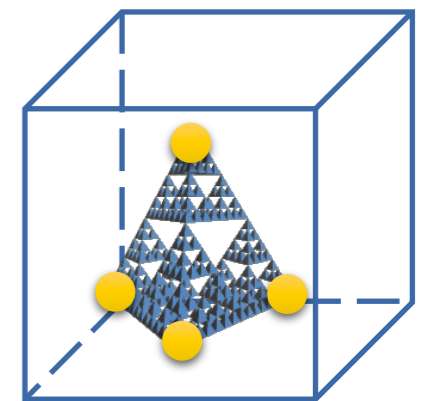
- Deep connections between quantum field theory, condensed matter and quantum information.

A Duality Web in 2 + 1 Dimensions and Condensed Matter Physics

Nathan Seiberg^a, T. Senthil^b, Chong Wang^c, and Edward Witten^a

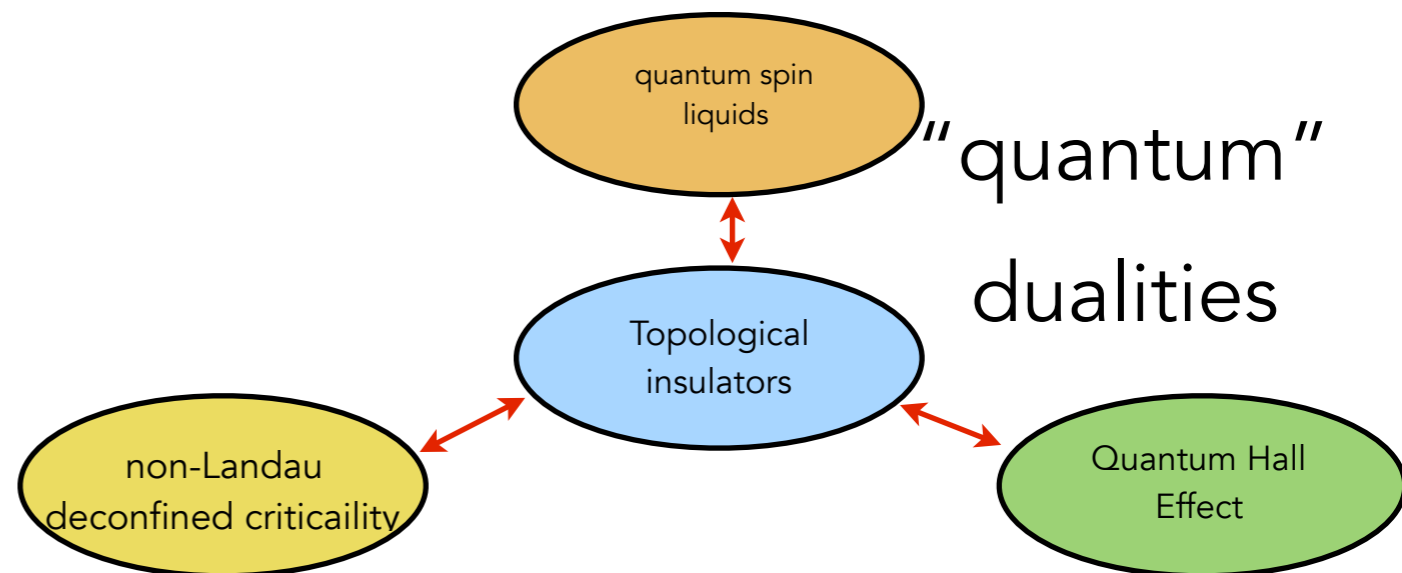


- Highly entangled quantum states closely related to quantum information processing.
 - Quantum Error Correction & Topological Order
 - Fractons & robust quantum memory
- Materials with entirely new properties? (eg. Higher Tc superconductors?)

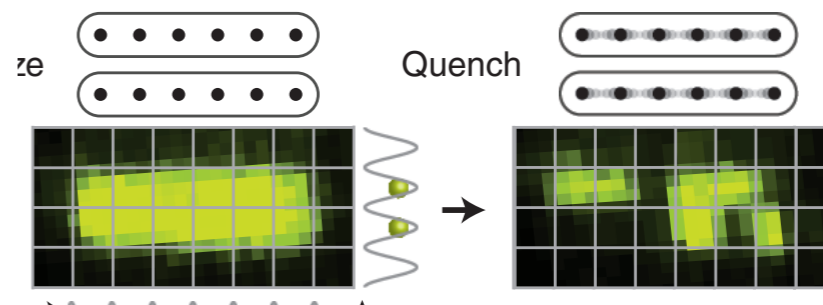


Why now?

- Remarkable relations derived between apparently distinct phenomena.



- Rapid improvements in probing and creating synthetic quantum systems.

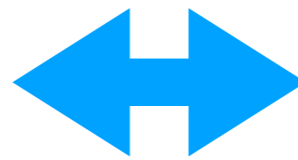
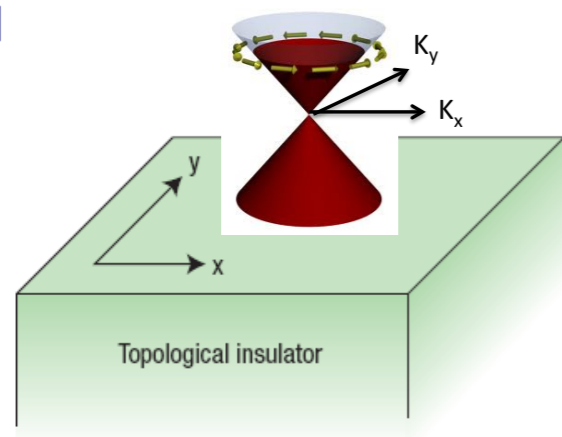


Measuring entanglement
Greiner lab. Proposed by Zoller et al.

A remarkable relation

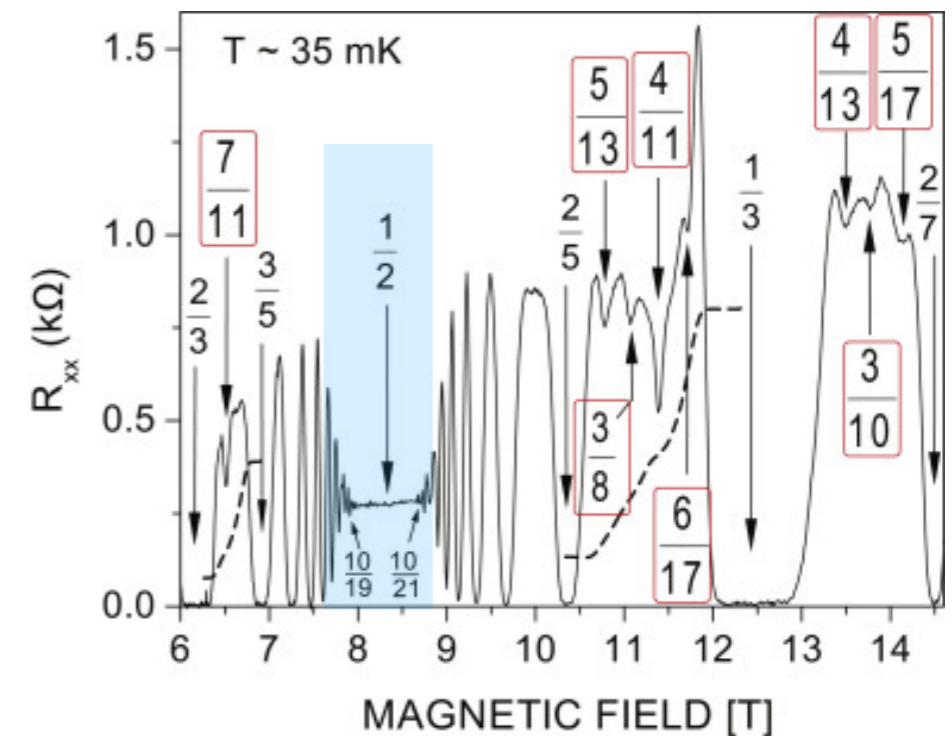
Topological Insulators

Fu, Kane, Mele, Moore, Balents, Roy,
Qi, Hughes, Zhang



Half filled Landau level

Halperin Lee Read



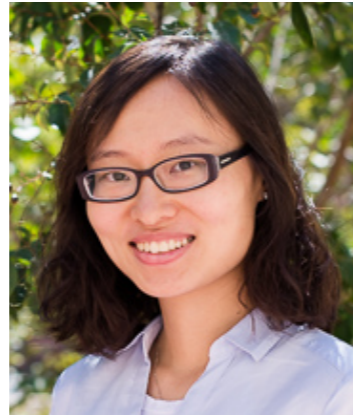
- Close relation between half filled Landau level and the *surface* of topological insulators.

[Gapped \leftrightarrow Gapless; 3D \leftrightarrow 2D]

- Fermion-Fermion electric-magnetic duality. (Son, Chong Wang & Senthil, Metlitski and AV, Seiberg, Witten, Karch & Tong, Kachru)



Michael Levin
Chicago



Xie Chen
Caltech



Max Metlitski
MIT

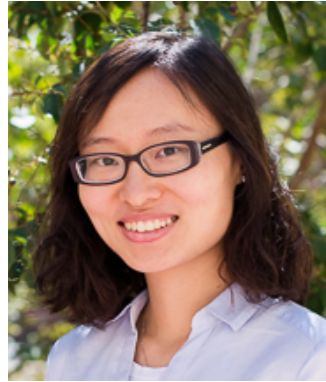


Lukasz Fidkowski
UW Seattle

2020 New Horizons in Physics Prize

For incisive contributions to the understanding
of topological states of matter
and the relationships between them.

Simons Collaboration Team



Xie Chen



Michael Levin



Ashvin Vishwanath



Michael Hermele



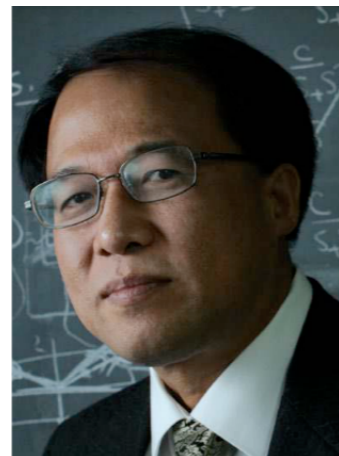
Dam Thanh Son



Andreas Karch



Victor Gurarie



Xiao-Gang Wen



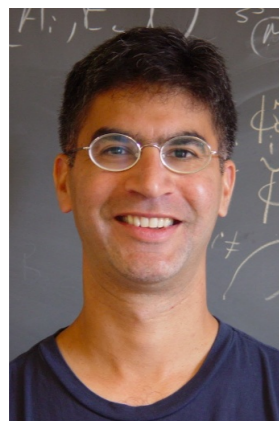
Nati Seiberg



Subir Sachdev



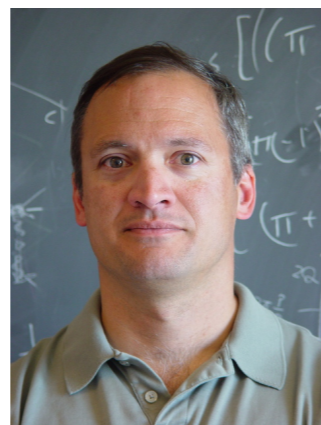
John McGreevy



Shamit Kachru



Victor Galitski



Leon Balents



T. Senthil



Matthew Fisher



Peter Zoller

9:45 – 10:30	Overview of Fracton UQM, and "Entanglement renormalization of fractonic gauge theories"	Xie Chen
10:30 – 11:00	"Higher symmetries, p-string condensation and fractons"	Michael Hermele
11:00 – 11:25	Break	Library
11:25 – 11:55	"Mimicking the edge of 2d topological insulators and superconductors in a 1d lattice model"	Max Metlitski