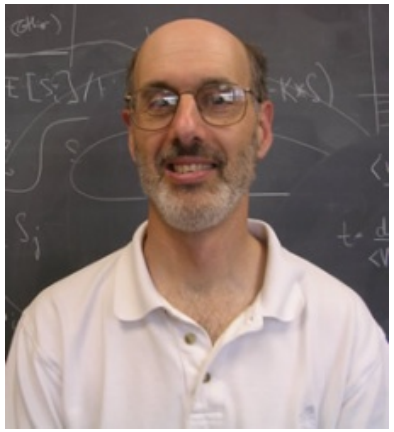
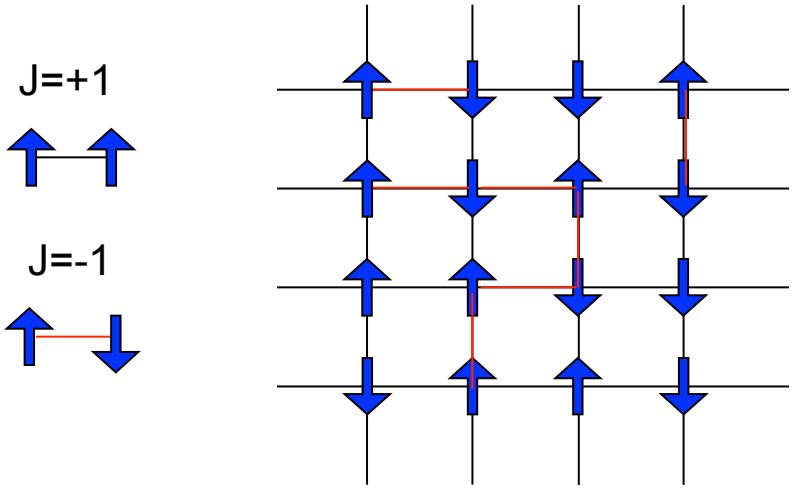


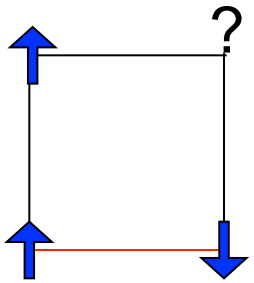
Jon
Machta

Statistical Physics of Complex and Disordered Systems

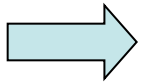
- ***Classical spin systems: algorithm development and computer simulations***
  - Ising model and various generalizations
- ***Computational complexity in statistical physics***
  - What is the difficulty of simulating various systems and how is that related to other properties?

Ising Spin Glass





Frustration!!



Rough free energy landscape

Algorithm development and large scale simulations using parallel tempering and population annealing.


Correlated Quantum Matter

http://people.umass.edu/qmatter/

http://mcwa.csi.cuny.edu/umass/

Boris Svistunov Nikolay Prokofiev

- ***Bosons: He-4, atoms in optical lattices (int. range, disorder, multi-component …)***
  - Supersolidity/superfluidity, phase diagrams, critical phenomena
- ***Fermions: neutron matter, Coulomb systems, Hubbard model, quantum magnetism***
  - Infinite number of interesting properties → who gets them first reliably → Diagrammatric Monte Carlo

High energy physics

Standard model

High-Tc superconductors

Fermi liquid

Quantum chemistry & band structure

Cooper pairs

Heisenberg model

Quantum magnetism

Periodic Anderson model

Heavy fermion materials

…

Introduced in mid 1960s or earlier

Still not solved (today is 10/17/2011)

Admit description by Feynman diagrams

Steven Weinberg, Physics Today, Aug. 2011 :

"Also, it was easy to imagine any number of quantum field theories of strong interactions but what could anyone do with them?"

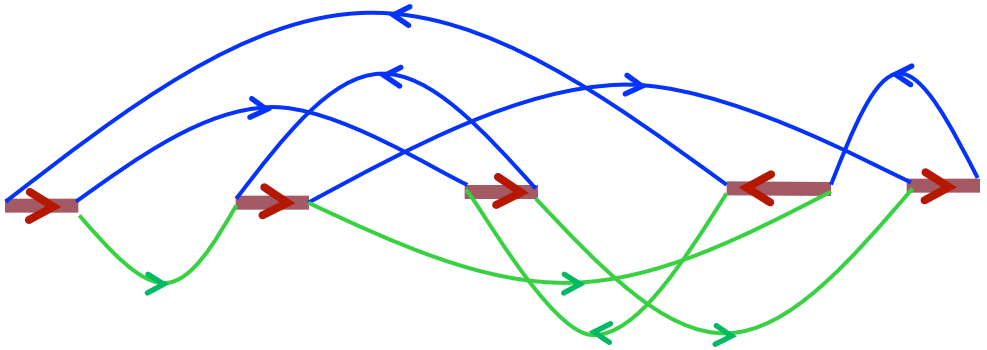
Teach computers (students first!) quantum field theory rules

Teach computers ( ) diagrammatic technique

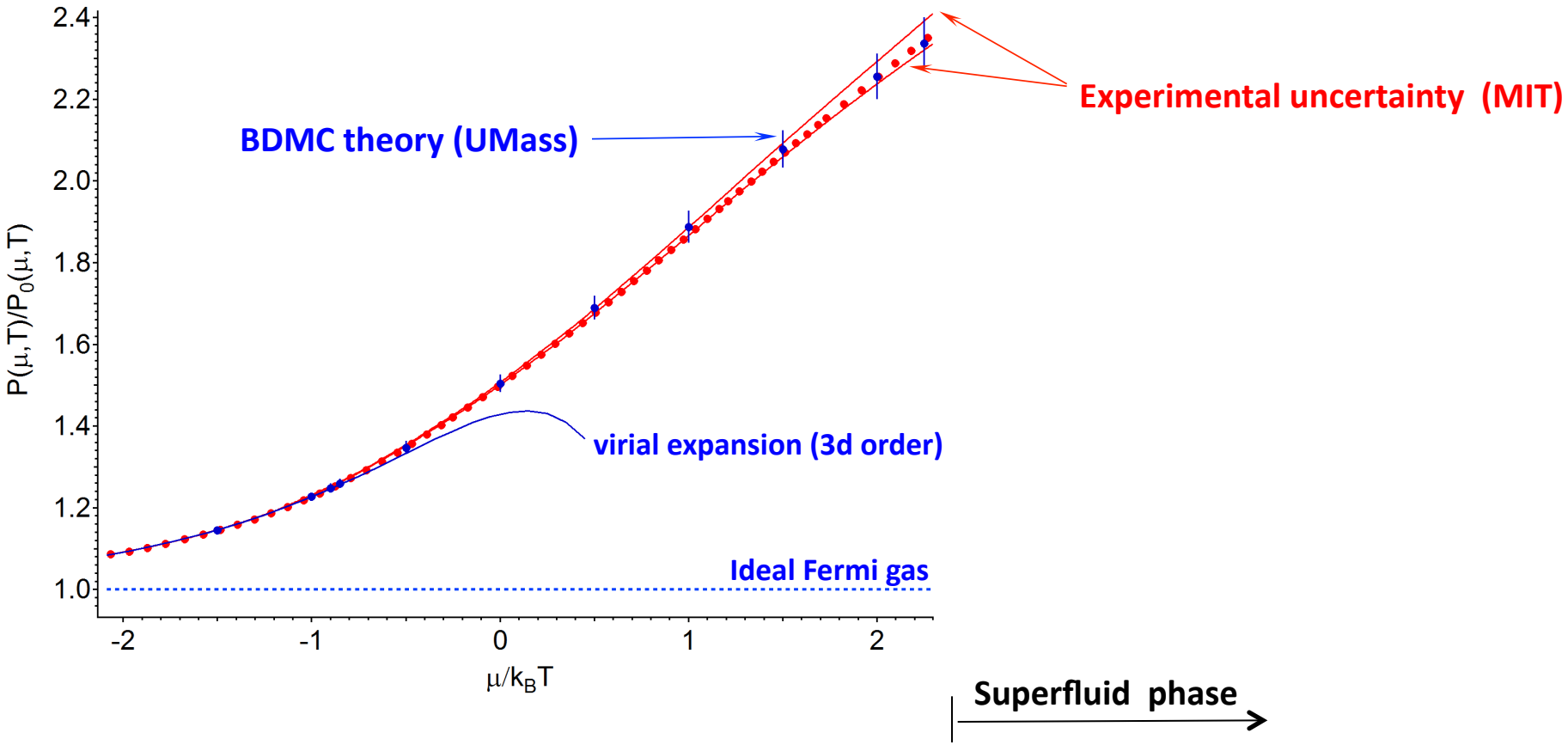
Compute tens of millions of skeleton diagrams

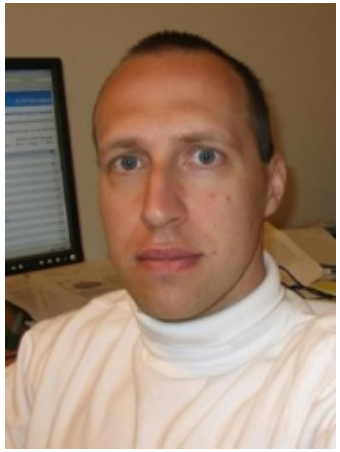
Pray for convergence / use resummation techniques and extrapolate to the infinite diagram order limit

$$Answer = \sum_{\text{You imagine!}}$$



Theory vs experiment (cold atoms solve neutron stars)

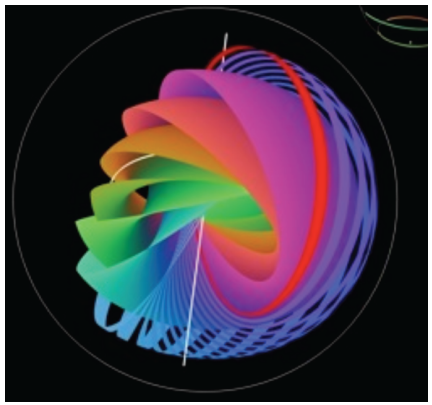


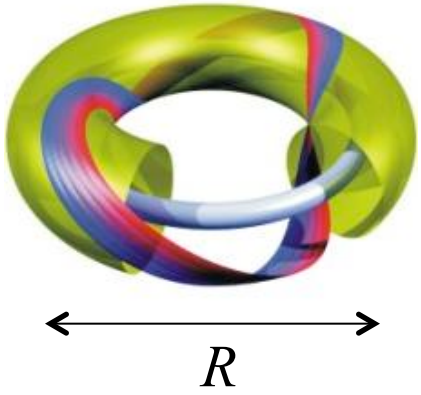


Egor Babaev

Multi-component superconductors

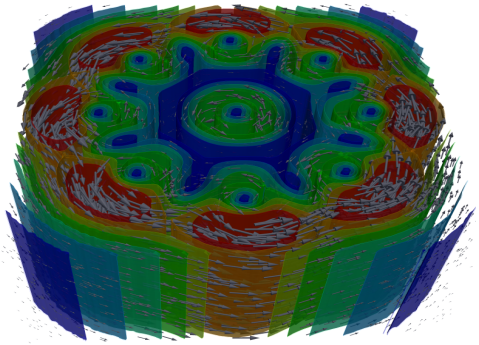
- ***Electronic systems***
  - Multiband materials, designed nanostructures
- ***Matter under extreme conditions***
  - Metallic hydrogen under pressure, neutron stars, bosonic mixtures in optical lattice
- ***Topological defects / excitations***
  - Vortex structures, type 1.5 superconductors, knot solitons

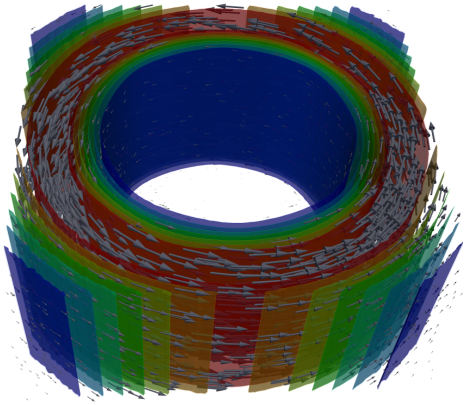




Knot solitons:

stability, E(R), realistic models?





The textbook classification:

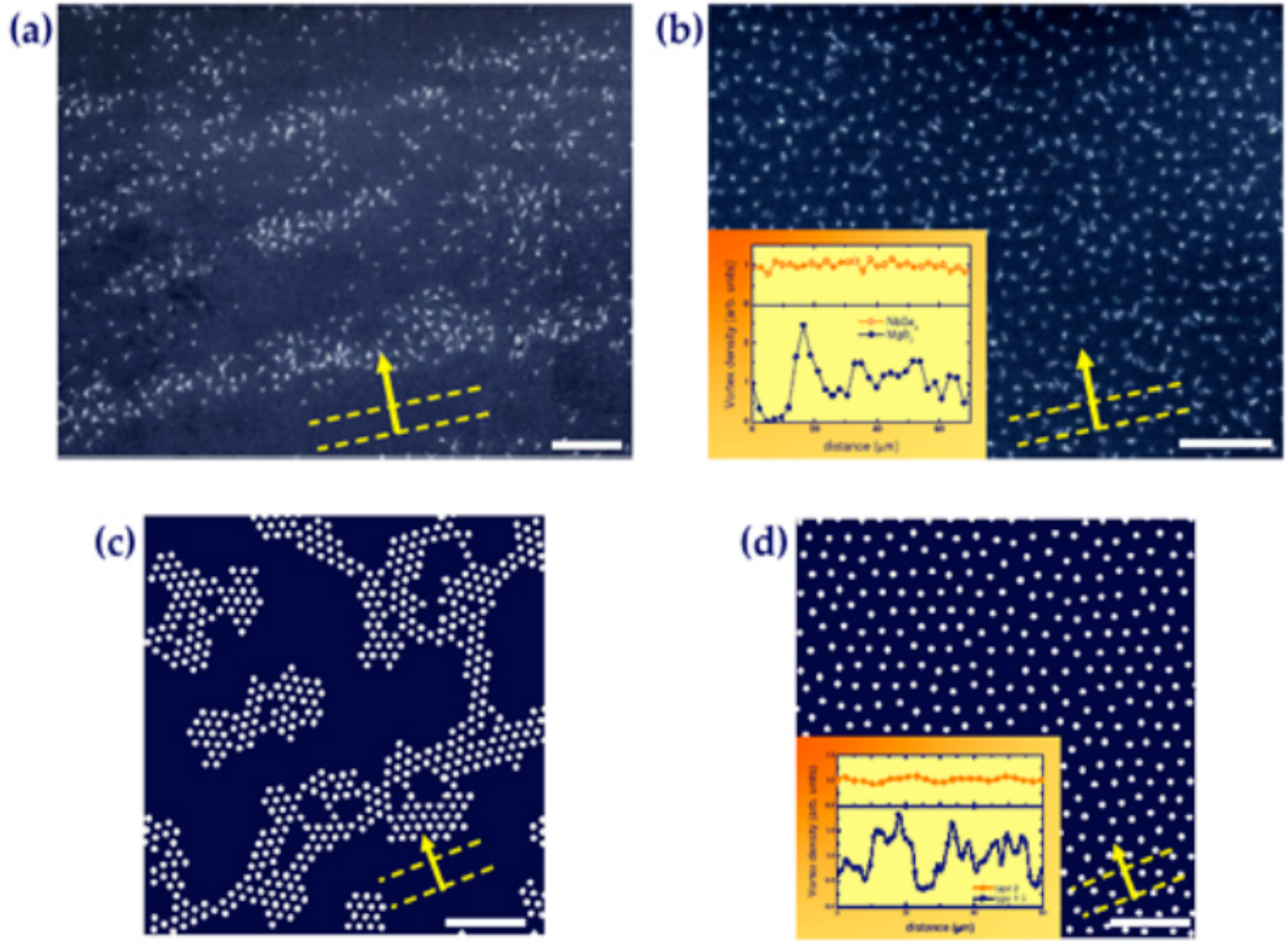
Type-I (vortices are not welcomed)

Type-II (vortex lattice in finite B; repulsive v-v interactions)

New Type 1.5 superconductors:

Vortex-vortex interactions are sign sign-alternating in multi-component systems – rich phase diagram of the vortex matter, clustering, etc. (see arXiv:1110.2744)

The images shows superconducting currents in type-1.5 superconductor in an external field.


(a)
(b)
(c)
(d)