Research Overview

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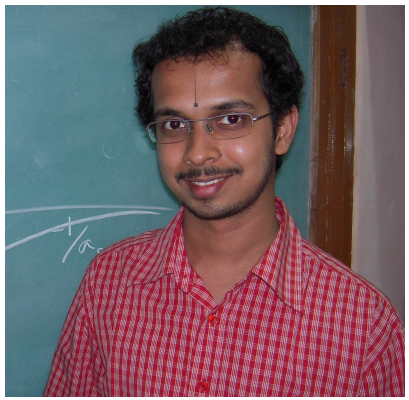
Research Group



Jayantha Vyasanakere

Sudeep Kumar Ghosh

Yogeshwar Prasad Saraswat

Amal Medhi

Vijay Shenoy

Research Interests

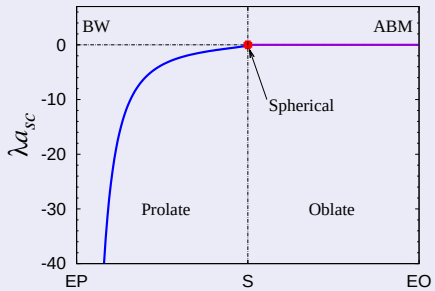
Theoretical quantum condensed matter physics

- Cold Atom Physics
- Graphene/Topological Insulators
- Strongly Correlated Electrons

Cold Atoms

Fermions in Synthetic Non-Abelian Gauge Fields

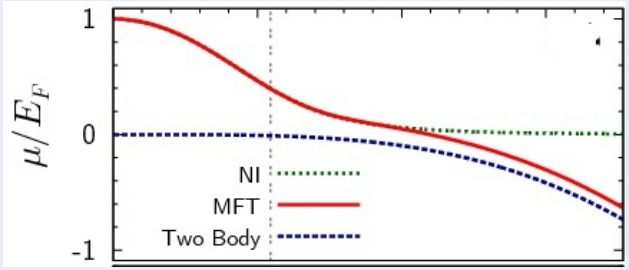
2-body



- Bound state for any attraction

arXiv:1101.0411

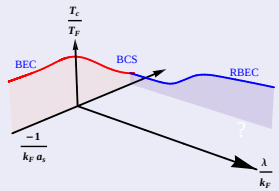
Many body



- Rashba SOC induces BCS-BEC
- Rashbon BEC

arXiv:1104.5633

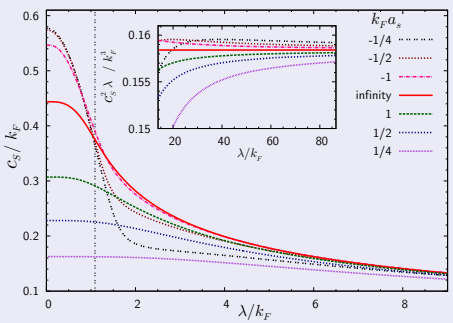
Rashbons



- Phase diagram, High T_c
- Pseudogap regime

arXiv:1108.4872

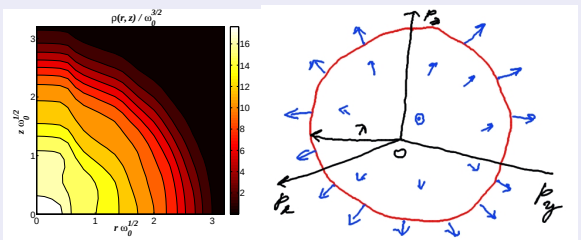
Excitations



- Emergent Galilean Invariance
- Rashbon-rashbon interactions

arXiv:1201.5332

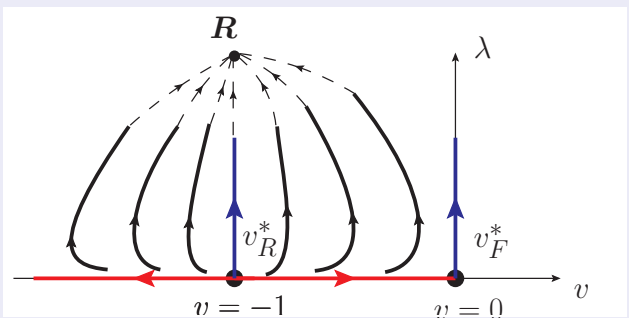
Traps/Potentials



- Shrinking of Clouds
- Novel Hamiltonians

arXiv:1109.5279

Overall RG Picture



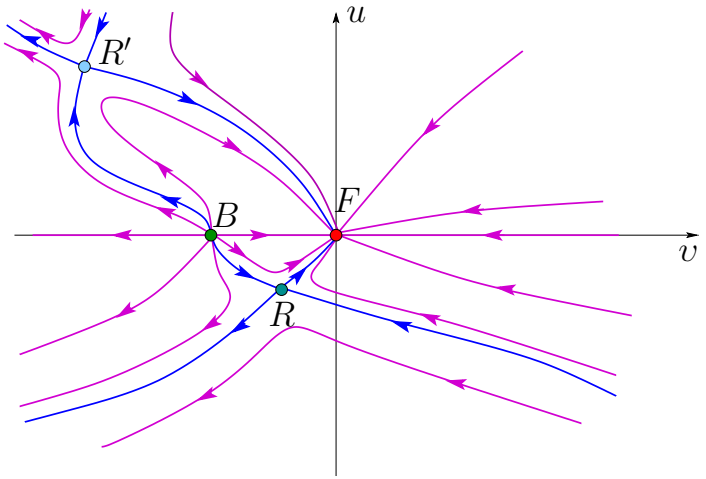
arXiv:1201.5332

Feshbach Resonances, Upper Branch Physics

- Broad and narrow Feshbach resonances

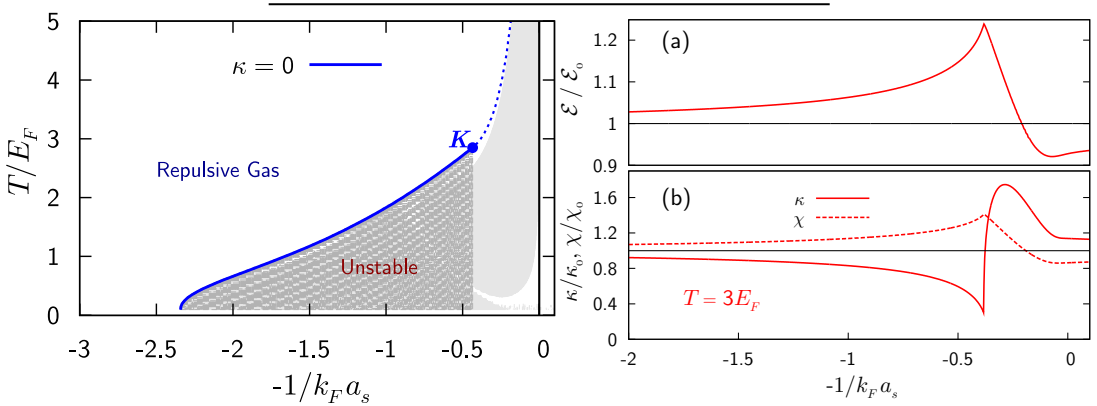
Feshbach resonances

RG flow diagram



(Unpublished)

Upper branch phase diagram



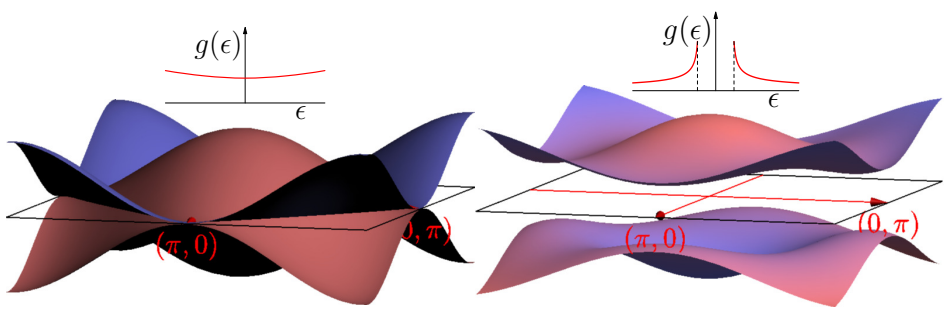
(1106.0960)

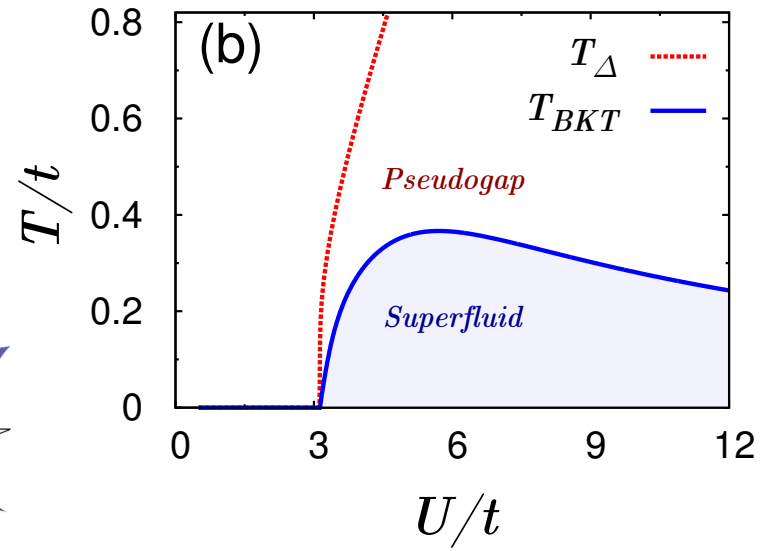
- Upper branch: Explanation of violation of Tan's theorem, no magnetic instability

Superfluid from Band Insulators

(1206.2407)

- Realization of a fermionic superfluid state in the 1-band TB limit
- Trick to overcome entropy removal problem – create a superfluid from a *band insulator*
- Tune *negative U* in a *bi-layer band insulator*



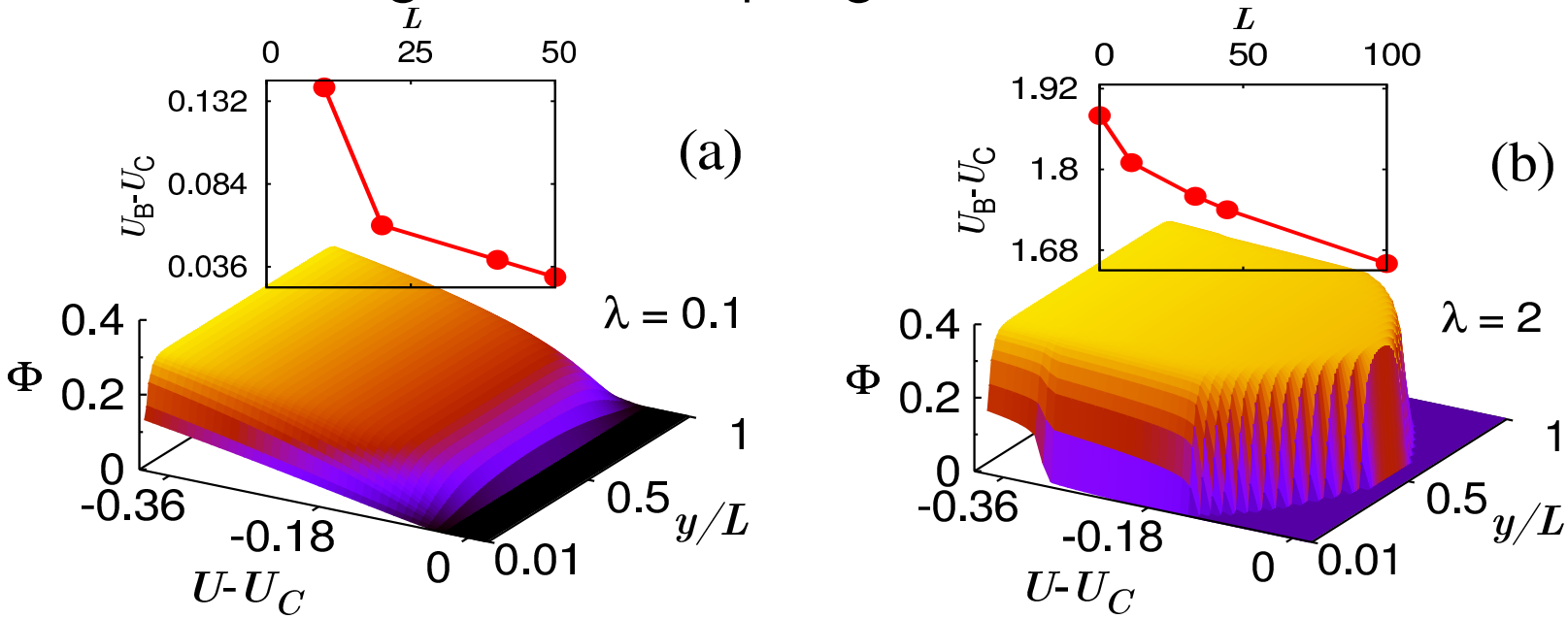


- Experimental realization: Orthogonally shaken bilayer

Topological Insulators

Correlation Physics in Topological Insulators

- Mott transition at edge states of topological insulators



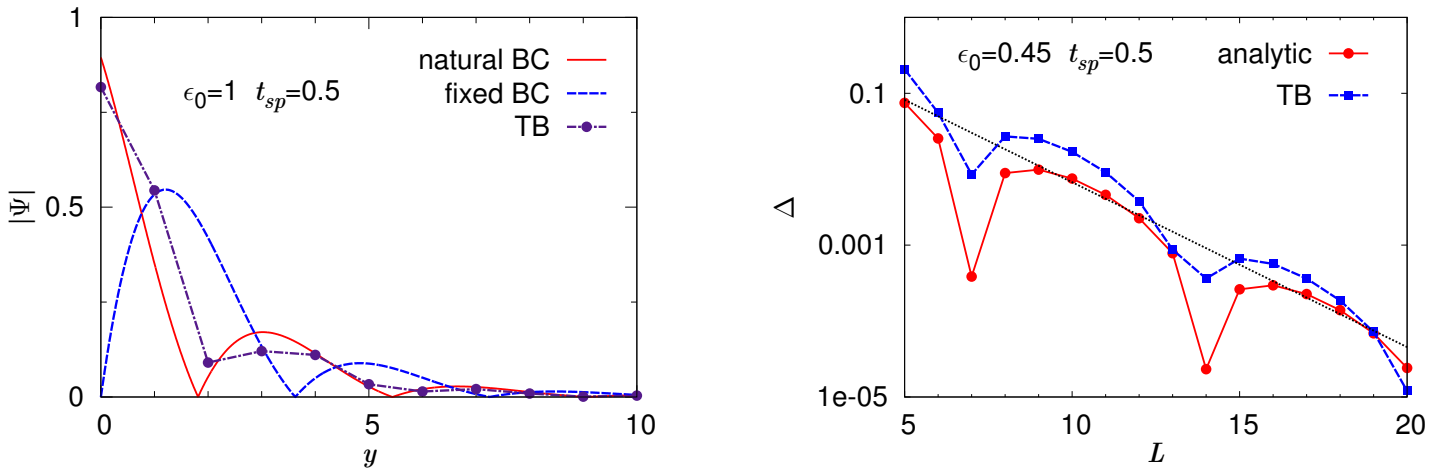
(Medhi et al., 1112.4308)

- Two routes: Synchronous and Asynchronous
- Determined by "topological resilience" – compressibility of the edge states
- Key message – All Mott physics is local!

Field Theories of Topological Insulators

- A continuum field theory to describe edge states of topological insulators in 2 and 3 dimensions
- A new *natural boundary condition* that correctly captures the nature of wave functions at the edges

$$n_i \left(S_{ij}^n \Gamma_{ab}^n \partial_j \Psi_b + i A_i^m \Lambda_{ab}^m \Psi_b \right) = 0$$



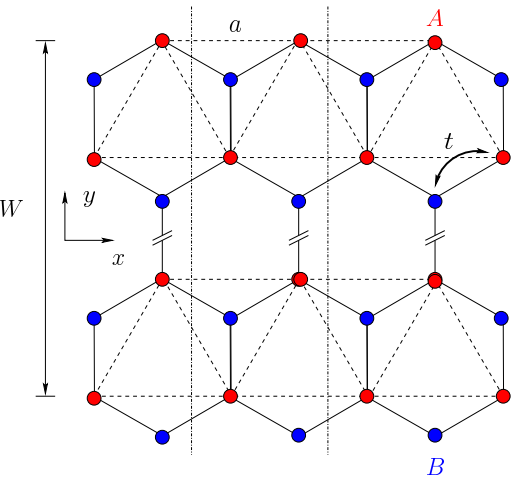
(Medhi et al., 1202.3863)

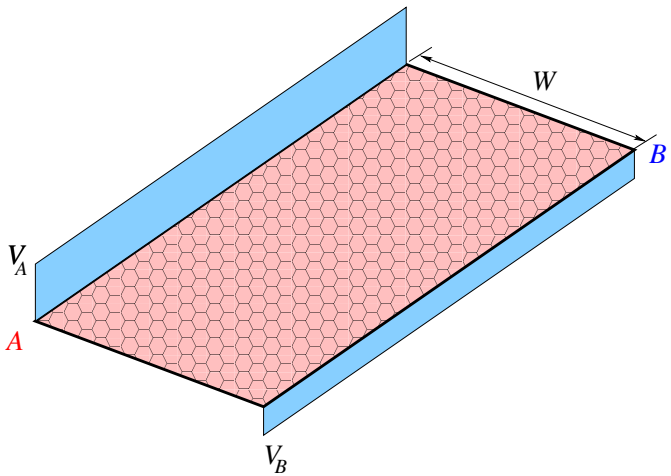
- Non-monotonic dependence of the gap on the thickness of ribbon! Possible applications?

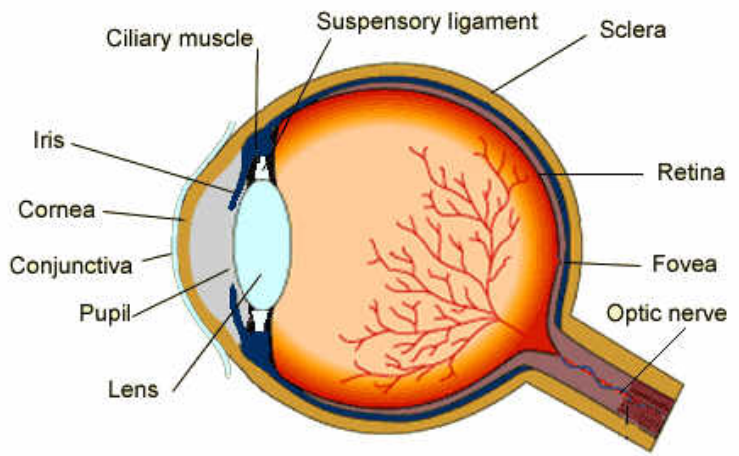
Graphene

Graphene: Sensory-organ like response

- Zigzag edge terminated nanoribbons subjected to *edge potentials*







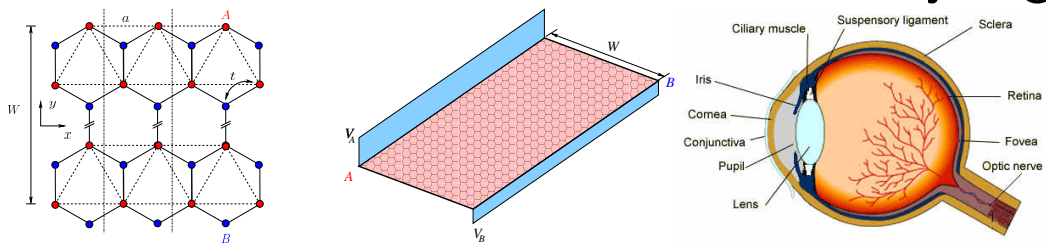
(Bhowmick, 1011.4736)

- ...show *Weber-Fechner* (sensory-organ like) response!

$$\Delta N \sim \mathrm{sgn}(V) \ln\left(\frac{|V|}{V_{th}}\right), \qquad V_{th} \sim te^{-W/a}$$

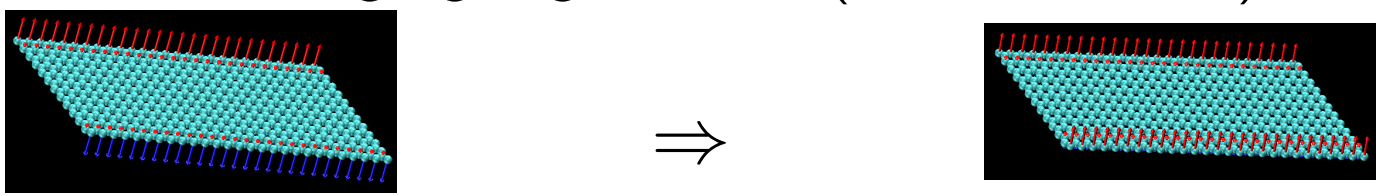
Graphene: Magnetism

- Zigzag edge terminated nanoribbons have sensory-organ like response!



(1011.4736)

- Magnetic structure of zigzag edge ribbons (Hubbard model)



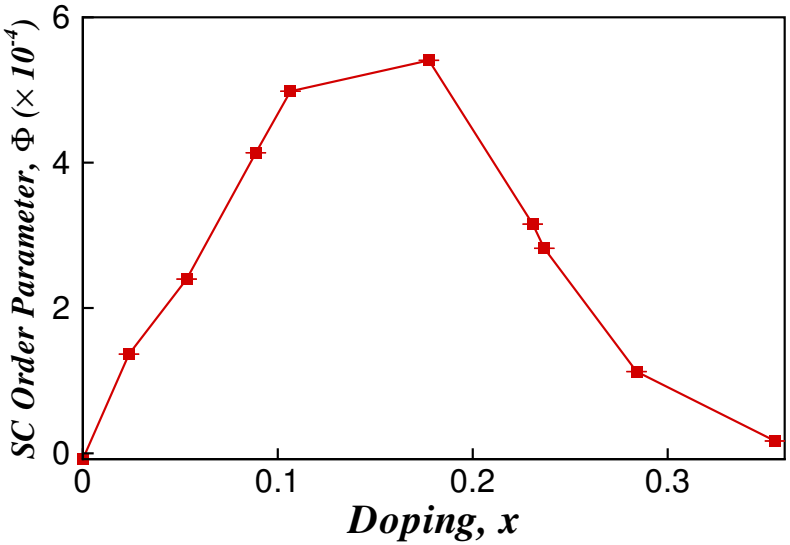
  - Undoped
  - Doped

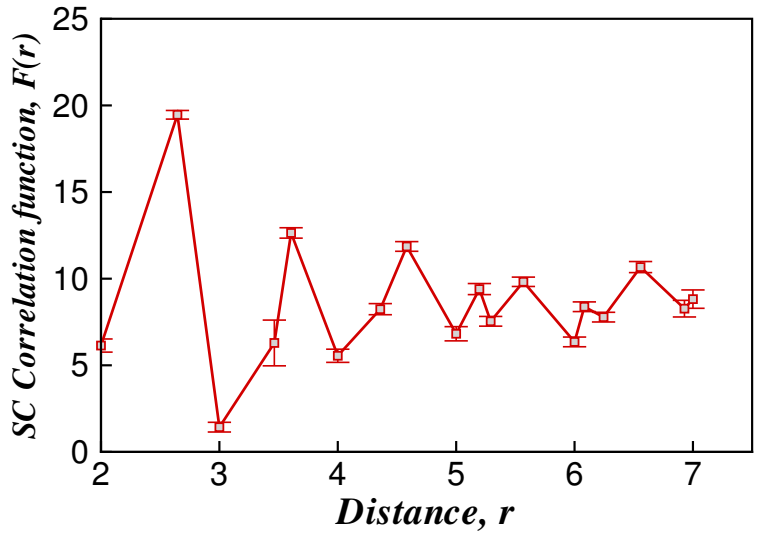
- First order transition from Anti-Ferro to Ferro as a function of doping...occurs at a *critical doping* (1208.3400)

$$\delta_c = C(U)\frac{a}{W}, \quad C(U) = \frac{1-\sqrt{1-\ln 3\left(1+\frac{2}{\ln(U/6)}\right)}}{\pi\left(1+\frac{2}{\ln(U/6)}\right)}$$

Graphene: Superconductivity

- Electron correlations drive superconductivity
- Pairing with $d + id$ symmetry





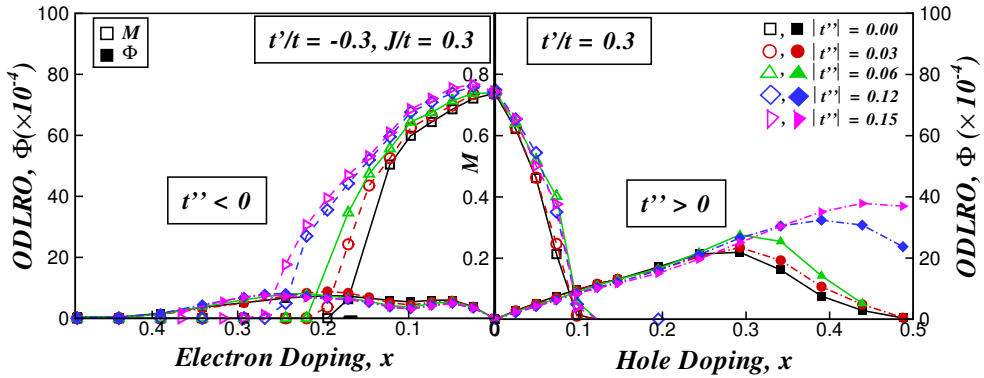
(0809.0244)

- Breaks time reversal symmetry
- Optimum doping around $x \sim 0.15$

Strongly Correlated Systems, High T_c

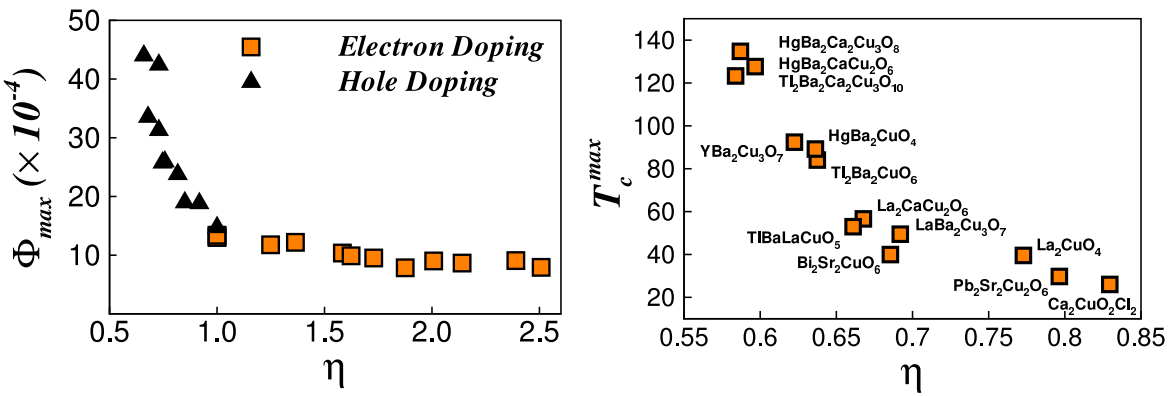
Strongly Correlated Electrons - High T_c

- Variational approach: Developed a new $O(N)$ method for optimization of variational wavefunction
- Material dependencies of the cuprate phase diagram



(Pathak et al., 2009)

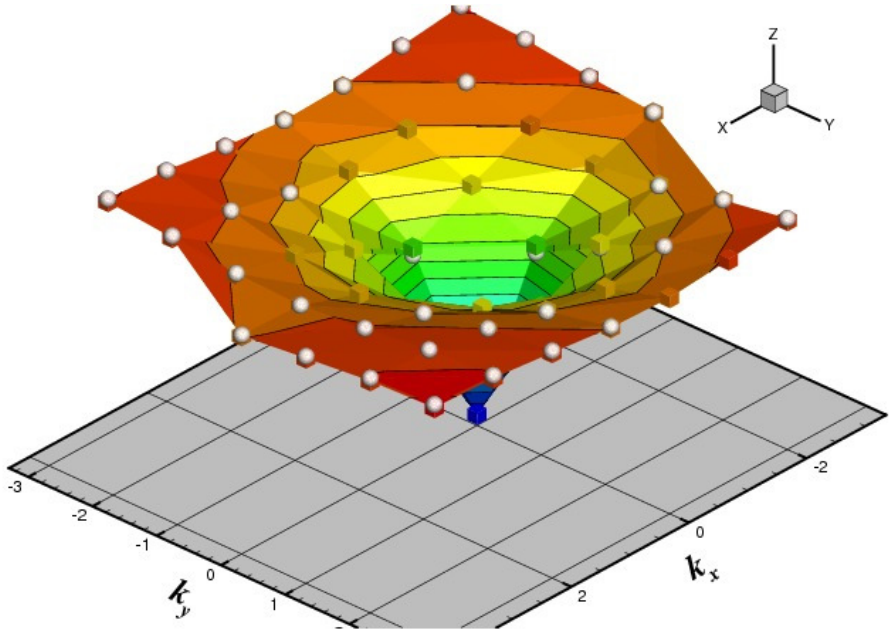
- Phase diagram determined by a single parameter FSCP

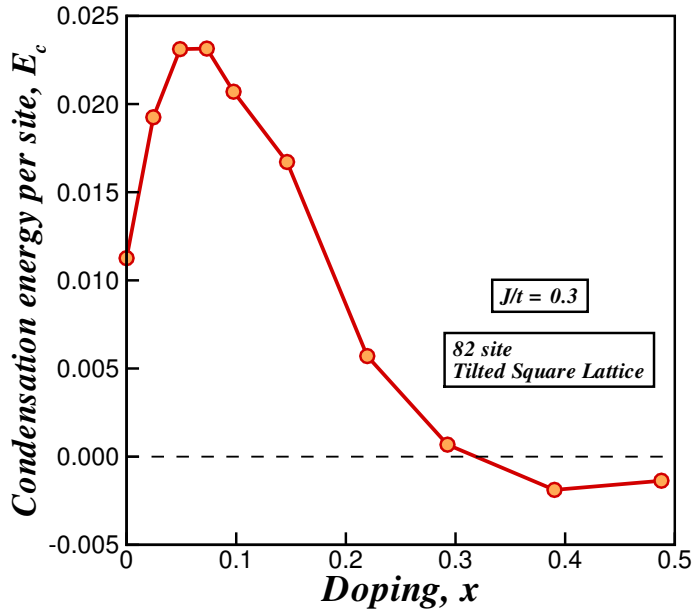


- Suggestions for raising T_c: Convex bare Fermi surface

Strongly Correlated 2D systems

- A general wavefunction for spin-singlet ground states





(Pathak, Ph. D. Thesis (2010))

- Estimate of condensation energy
- In the extremely correlated liquid ($U = \infty$), Luttinger theorem holds

Vijay Shenoy, Brief Vitae

- B. Tech (IIT Madras, 1992), M. S. (Georgia Tech., 1994), Ph. D. (Brown, 1994)
- Publications: $\gtrsim$ 65, Hirsch Index: 27
- Ph. D. supervised (3): Murali Palla (2008, Post Doc Singapore), Somnath Bhowmick (2010, Post Doc Upssala (Sweden), Offered faculty position at IIT Kanpur), Sandeep Pathak (2010, Post Doc UC Santa Cruz)
- Recognition: Fellow IAS, Raja Ramanna Prize (2011), DAE-SRC Outstanding Research Investigator (2010), NASI-Scopus Young Scientist Award (2009), Ramanujan Fellowship (2007), INAE Young Engineer Award (2005), INSA Medal for Young Scientist (2002), Associate, Indian Academy of Sciences (20012006), IITK Director's citation for outstanding tutor (2000), Elected Member of Sigma-Xi (1998), Brown University Teaching Fellowship (1998), Caltech Special Fellowship (1997), Brown University Fellowship (1994-95)
- Visit home page `www.physics.iisc.ernet.in/~shenoy` to download latest papers