# Final Thoughts

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**Higher Temperature Superconductors**

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# Search for higher Tc's **

Challenge: Enormous phase space

Two approaches:

1. Solid state chemists and physicists trying "crazy" things

2. Guidance from theoretical understanding

Past successes: Nb3Sn, Si under pressure, doped C60, metallic nanotubes,…, CeIn3 (3d) → CeCoIn5 (2d),… [Marvin Cohen]

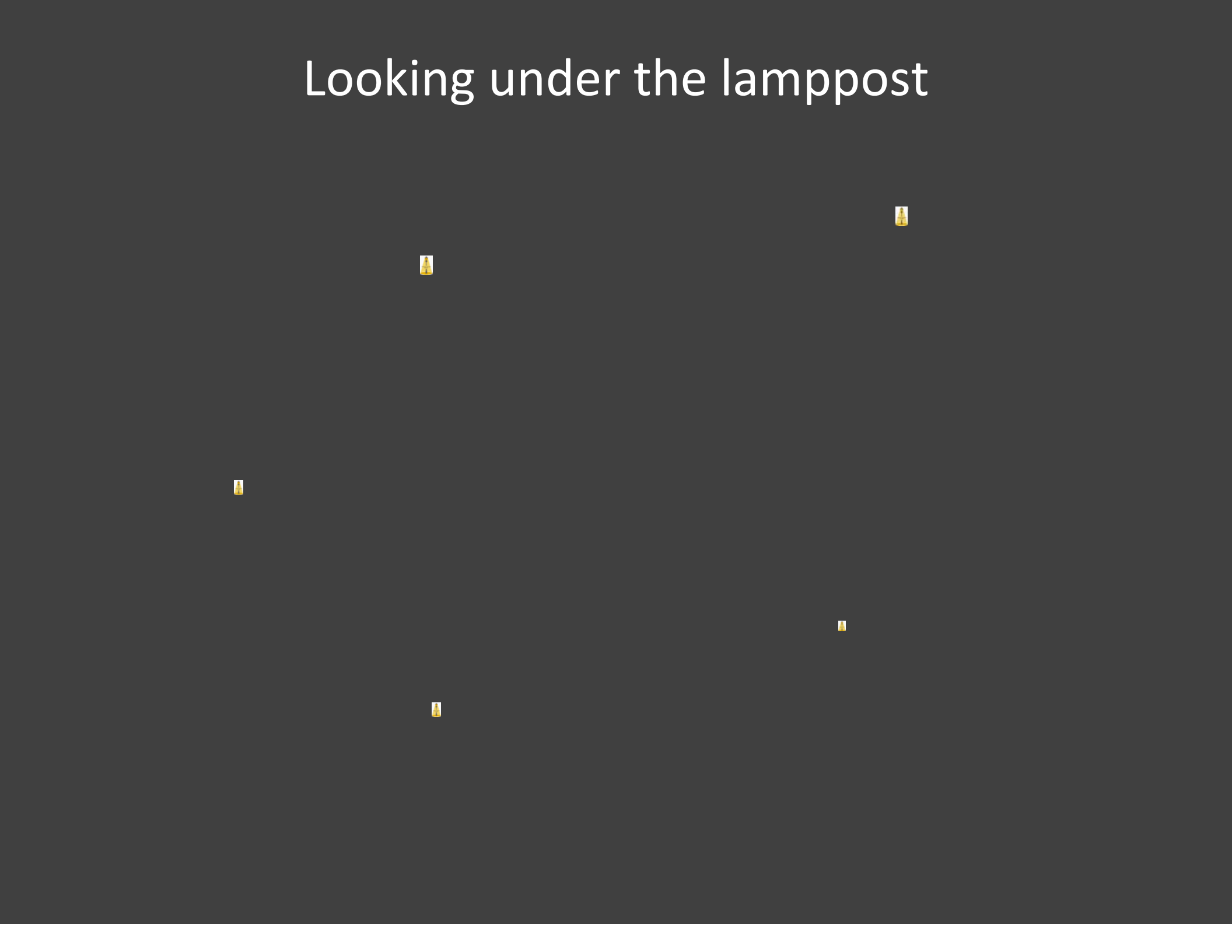
** Need high $J_s$ , too! - Mac Beasley

# Looking under the lamppost





# Looking under the lamppost



# Class 1 (el-ph) guidance

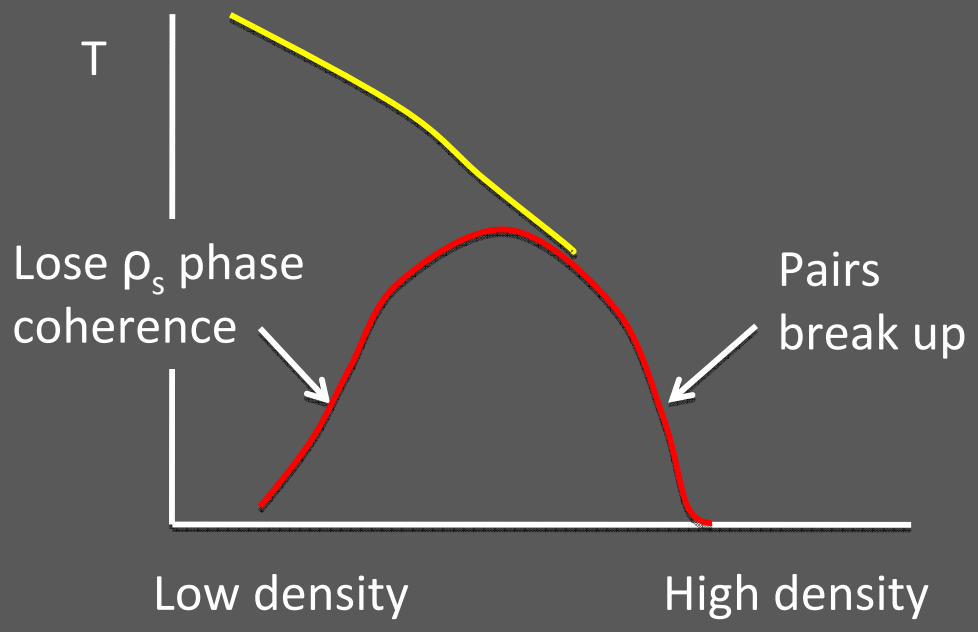
Canfield, Cohen, Pickett

- Light atoms, strong el-ph coupling (but no structural transition – caged structures good), high $N(E_F)$, 2d, strong electronic bonds, engineered band structure

- Well understood and promise for higher Tc's→ specific predictions?

- Potential for high Tc's in hybrid systems?

# Cuprate inspired guidance




Tc is optimized for

- optimal doping (crossover between pairing and condensation regimes)
- U~W (near Mott Insulator transition; intermediate coupling →ξ~a)

→ the cuprates are already fairly well optimized . Improve by increasing t& U.

Inhomogeneity – doesn't hurt or actually helps? Is there an "optimal inhomogeneity"? [Kivelson]

Is there an "optimal frustration"? Get rid of nodes (s+id)?

Composite system with strong pairing (UD) separate but coupled to large carrier density (OD).

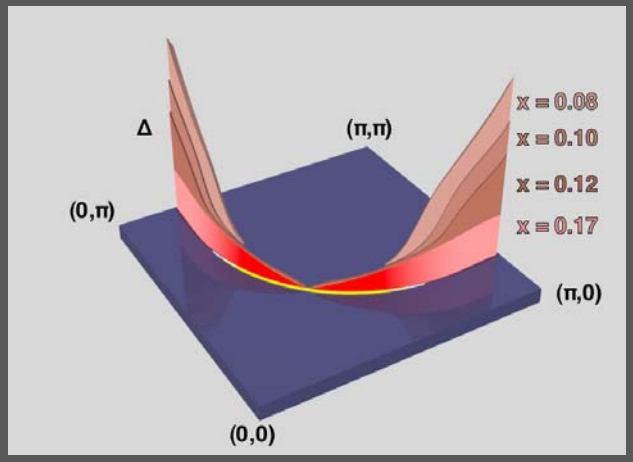
How do we identify materials with strong SC pairing but low Tc?

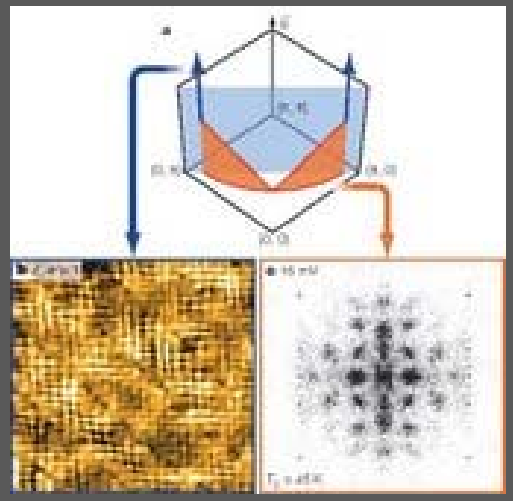
# Fe Pnictide inspired guidance

- Optimal polarizability to reduce on-site Coulomb repulsion
- Fe-As-Fe angle is 70° (need < 90°) → attractive contribution to nn interaction
- Pnictides do a good job of optimizing, but can one design structures using highly polarizable atoms alternating with narrow band metal film for higher Tc's? [Sawatzsky]

- Cuprates and pnictides lead to ideas of separating carriers and glue, doping and carriers, pairing and phase coherence, optimize doping and bandstructure→ use interfaces [JochenMannhart, Peter Abbamonte, Ivan Bozovic]

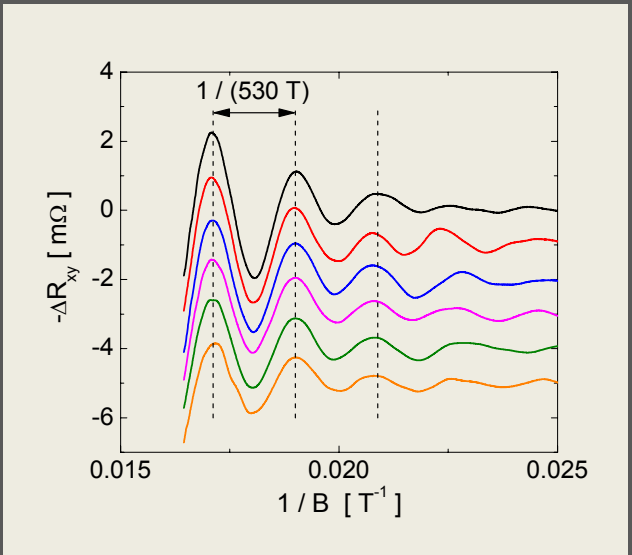
# High Temperature Superconductivity in Cuprates



- [Davis, Yazdani] Universal nodal qp in vanishing `arcs' as doping decreases and incoherent excitations with large pseudogap at antinodal points. Conjectured valence bond glass. Two gaps, but really strongly correlated system with coherent and incoherent spectral weight.

# High Temperature Superconductivity in Cuprates




•Quantum Oscillations [Suchitra Sebastian] – 3 frequencies in YBCO-6.5, attributed to reconstruction of large Fermi surface due to field induced SDW. Also m* strongly increases with reduced doping. Senthil explains this as vortex liquid state and qp scattering off fluctuating Δ. Large pseudogap at anti-nodal points does not close, but some spectral weight shifted to low energies.

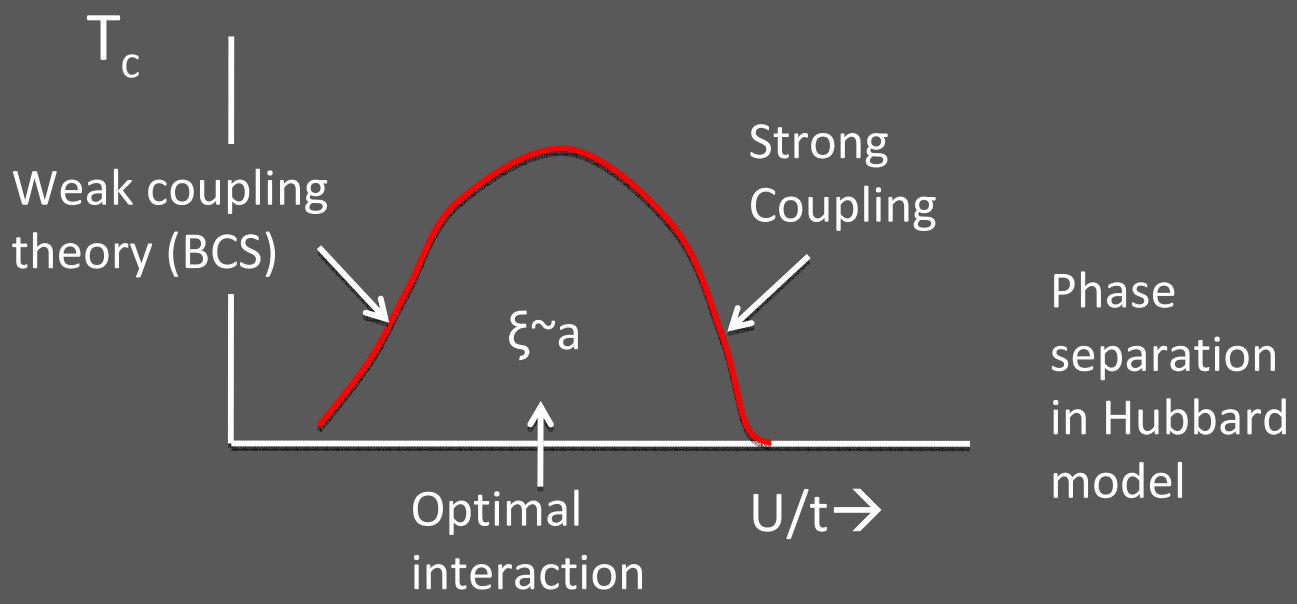
# Emergent spatial structure in (mostly) Cuprates

- Static electronic inhomogeneity which break translational and rotational symmetry at the large pseudogap energy scale (Davis, Yazdani). Tendency toward nematic order? (Eun-Ah Kim)
- Evidence of fluctuating stripes in UD regime (John Tranquada)
- Loss of phase coherence at Tc in UD regime supported by STM (qp interference).

- STM also sees static stripy modulations in UD pnictide in AF state oriented along a-axis → large inplane anisotropy in detwinned crystals.

- Cuprates have tendency toward stripes, but are they central to (or help) high Tc and/or to pseudogap?

# High Tc Superconductivity in Cuprates

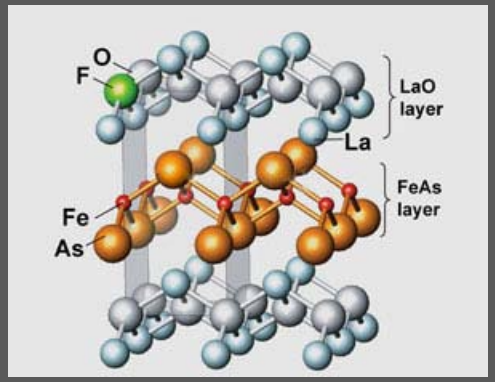



•Eliashberg calculations starting from NFL (Chubukov) and numerical motivation (dynamic cluster MFT – Kotliar, Scalapino) → pairing glue. Eliashberg is used in interpreting various expts, but caution is needed.

• RVB (Anderson) and strange metal (Fisher) have no electron-like qp→ no pairing glue. Very difficult, but important, problem.

• What is $T_c$ of the Hubbard model on a square lattice with U ~ 8t? What "decorations" would make it higher?

# Fe Pnictides




•Pnictides are not the same as the cuprates.

• Pairing mechanism, symmetry and role of correlations still to be sorted out, but evidence points toward renormalized band structure, not to lightly doped Hubbard bands.

• Need to test for s± gap symmetry

• SDW order appears to compete with superconductivity, so that Tc could be increased if one could frustrate this order while maintaining pairing interaction. Unlike cuprates, Drude weight non-vanishing in SDW regime. [Vishwanath]

# Other connections

- Doped spin liquids as a route to higher Tc superconductors? Kazushi Kanoda finds superconductivity is not enhanced by proximity to spin liquid behavior.

- Superconductors with topological insulators →Majorana fermions, non-abelian statistics and quantum computing? [ZahidHasan]

# The end