Hirschfeld research group

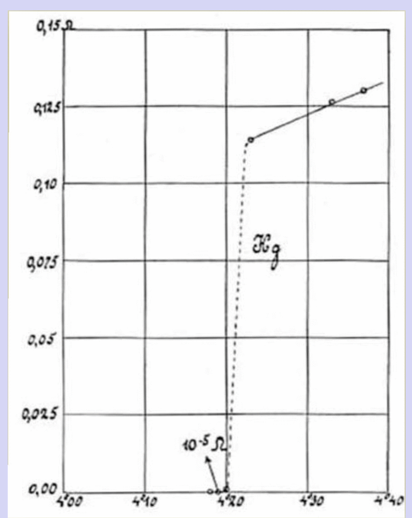
Background: Superconductivity

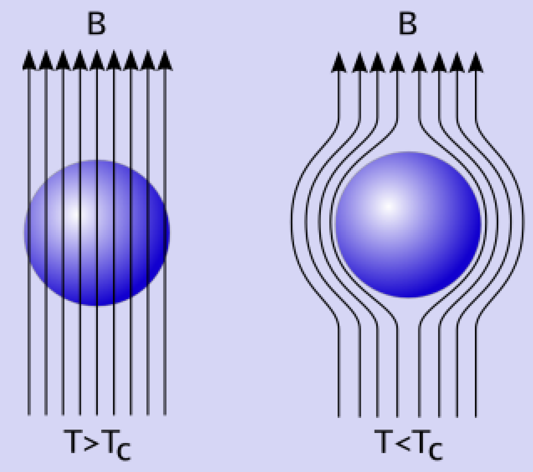
a) thermodynamic phase at low temperatures characterized by
- zero resistance (important for technical applications)
- ideal diamagnetism (Meissner effect, full expulsion of magnetic fields)

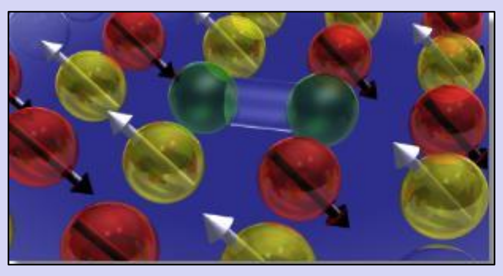
b) formation of Cooper Pairs due to attractive interaction and their condensation leads to superconducting properties

c) Origin of attractive interactions
- Phonons: Fröhlich mechanism (realized in conventional superconductors)
- Spin-fluctuations / orbital fluctuations (most probable mechanism for high T_c superconductors)

Discovery of Superconductivity: Measurement of the resistivity of Hg at the temperature of liquid Helium (Kamerlingh Onnes, 1911)







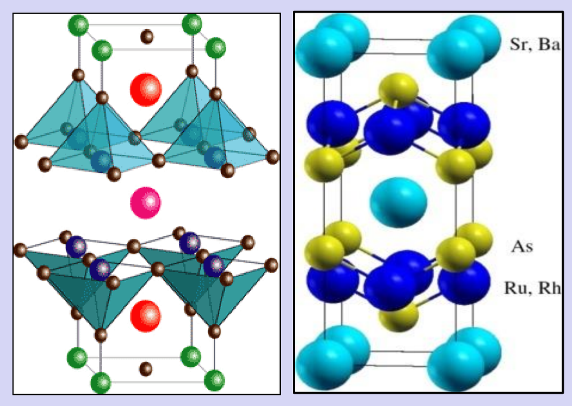
Two electrons with opposite spin combine to form a Cooper pair (green) that follows the statistics of bosons. The pairs can then condense and form a macroscopic quantum state

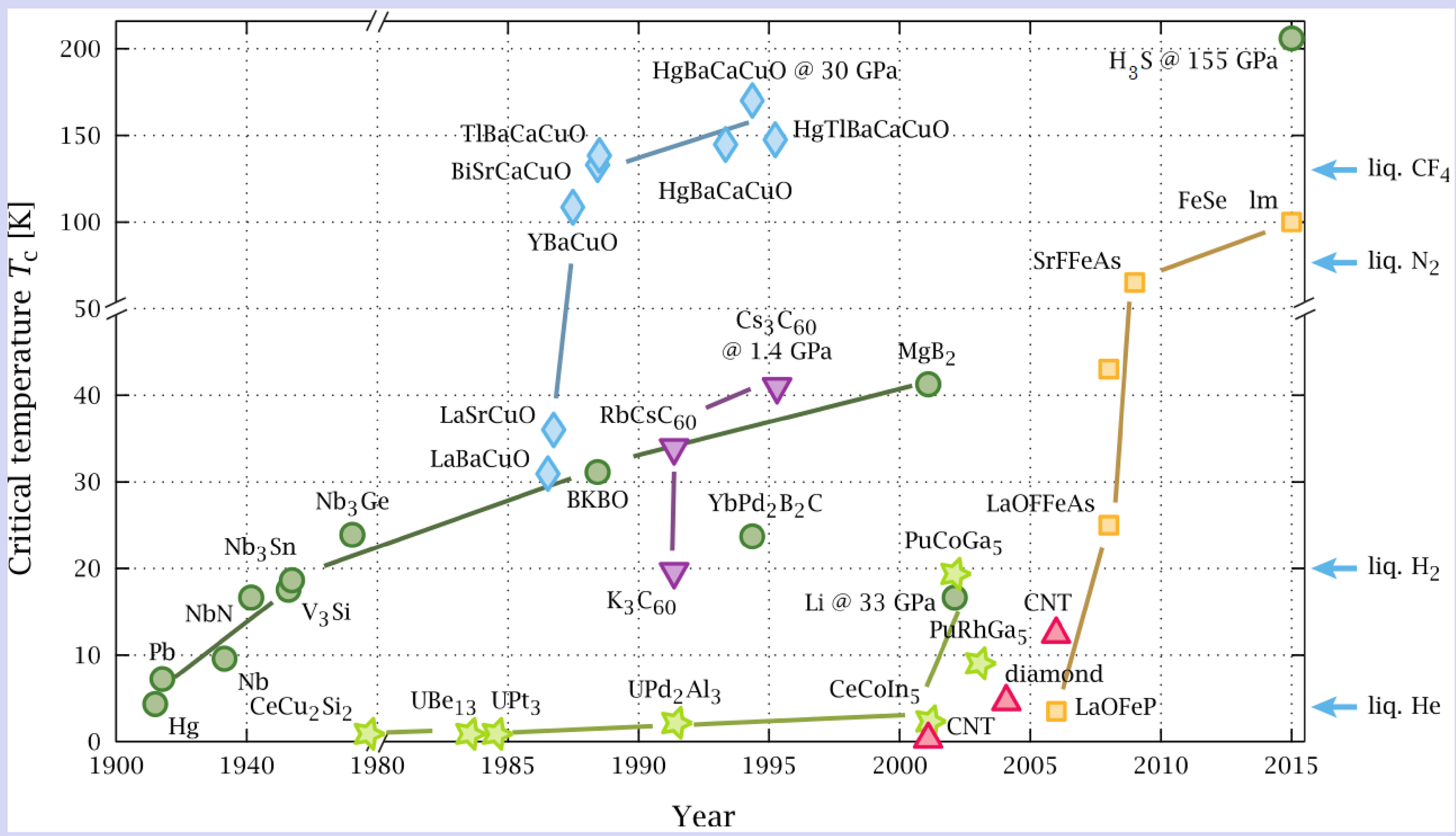
Known materials:

a) conventional superconductors: simple materials with strong electron-phonon interaction.

b) Cuprates (discovered 1986): high-temperature superconductors with complicated layered structure,

c) Iron-based (discovered 2008): superconductivity in vicinity of magnetic ordering.





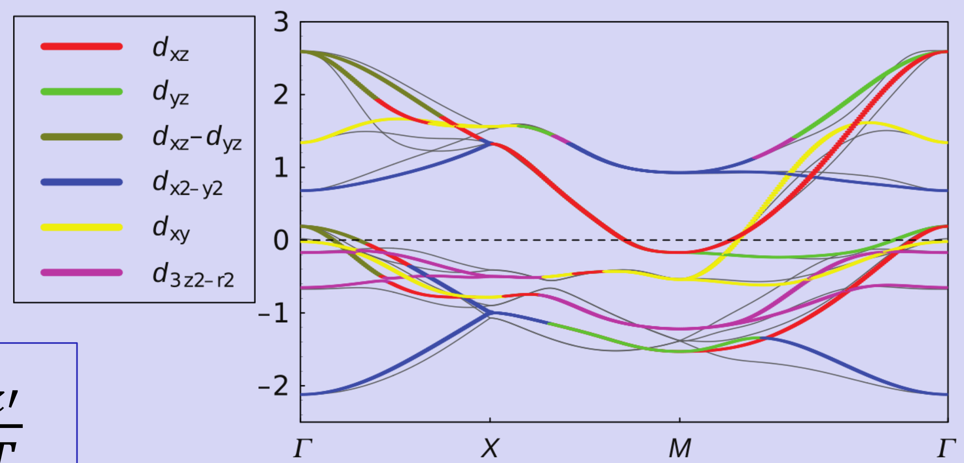
Research topics

a) Iron-based superconductors spin-fluctuation theory: "glue" for Cooper pairs

$$\Delta_k = -\sum_{k'} \Gamma_s(k,k') \frac{\Delta_{k'}}{2E_{k'}} \tanh\frac{E_{k'}}{2T}$$

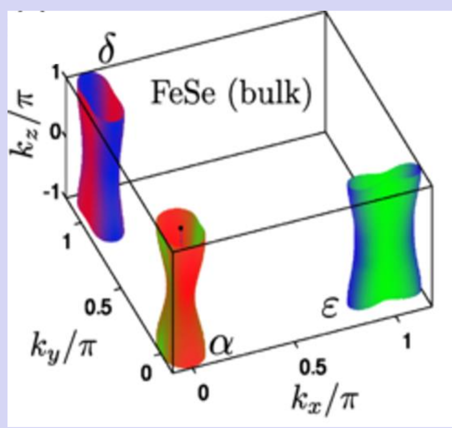
superconducting gap (order parameter)

pair scattering vertex

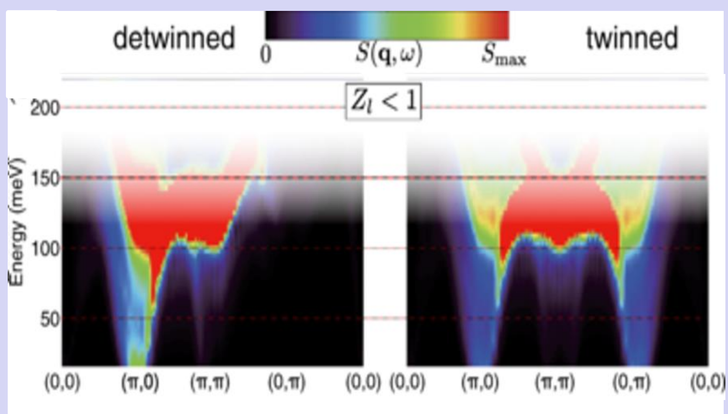


LaOFeAs: Bandstructure in 5-orbital representation, Graser *et al.* (2009)

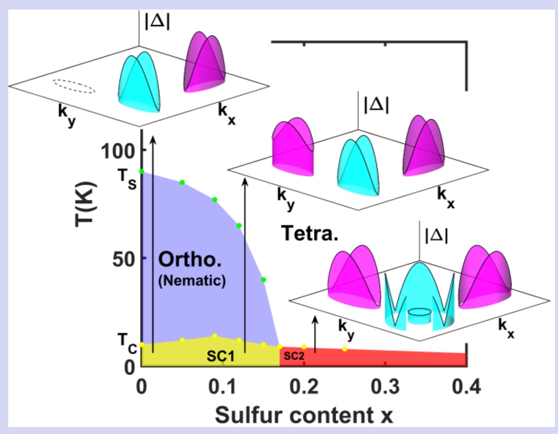
Recent project: superconductivity in FeSe



Fermi surface with different Fe 3d-orbital weights indicated by color: xz:red; yz:green; xy: blue.

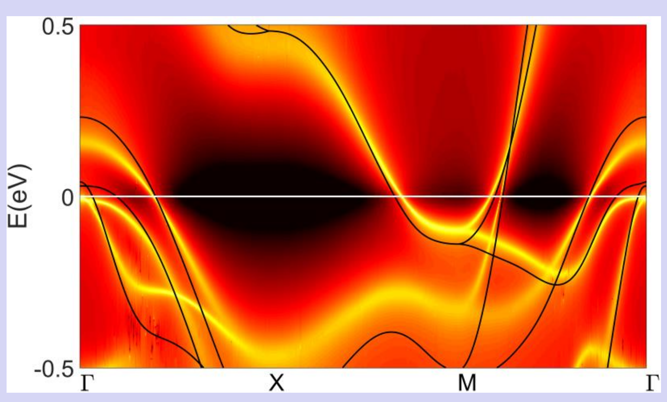


Momentum cuts of the dynamical structure factor $S(\mathbf{q},\omega)$ for detwinned (left) and twinned (right) crystals of FeSe with incoherent quasi-particle weights. Kreisel et al, PRB (2018).

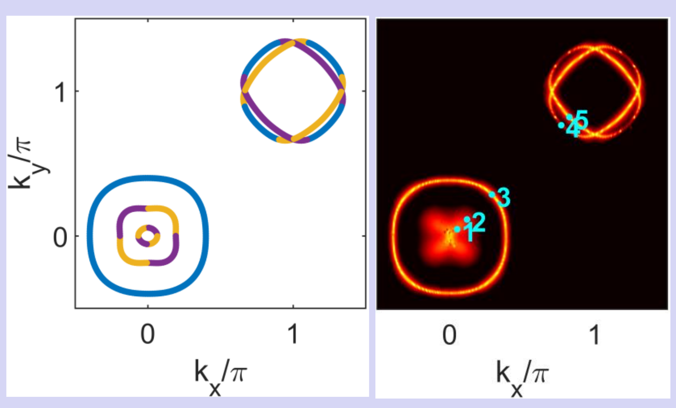


Schematic plot of phase diagram and intra-pocket order parameters for bulk $FeSe_{1-x}S_x$. Setty et al, arXiv (2019).

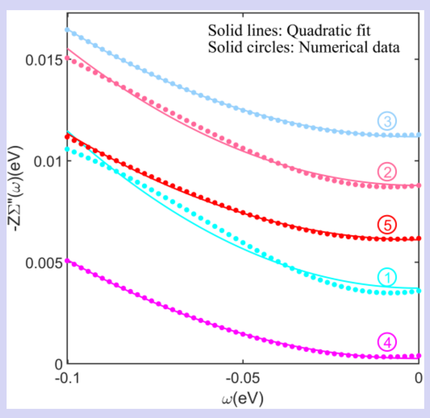
Recent project: Non-local correlations effects in Fe-based Superconductors



Spectral function of LiFeAs under self-energy renormalization effect. Non-interacting bands shown with black curves.



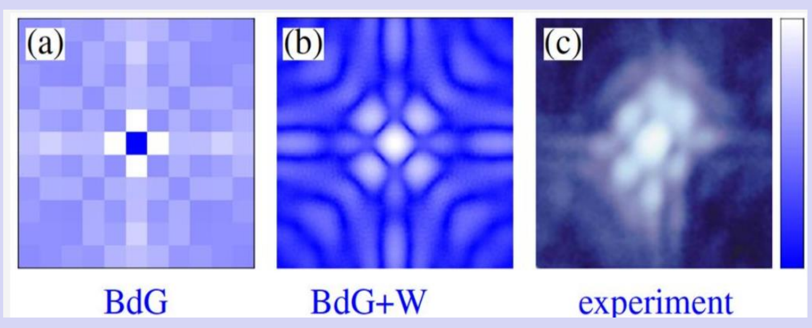
Fermi-surface at $k_z = \pi$ plane for LiFeAs: (Left) in non-interacting system, (Right) under interactions. Work in progress by Bhattacharyya et al.



Scattering rate calculated at different momentum points in LiFeAs.

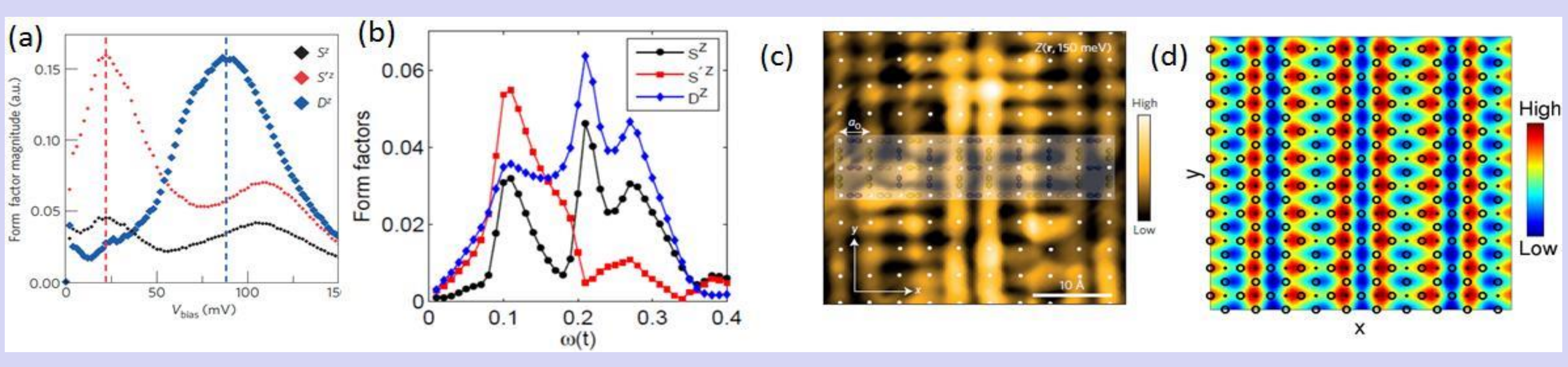
b) Cuprate superconductors:

Recent project: Impurity states in BSCCO



Calculation of Zn impurity in BSCCO-2212 (Kreisel et al PRL 2015): a) traditional Bogoliubov-de Gennes (BdG) solution; (b) BdG+W approach from Choubey et al PRB 2014; (c) expt. from Pan et al Science 2001.

Recent project: charge order imaged by STM in BSCCO



(a), (b) s, s' and d-form factors in BSCCO-2212 vs. STM bias: (a) experimental results from Hamidian et al, Science (2015) (b) Theory of Choubey et al, NJP (2017). (c), (d) conductance maps: (c) BSCCO-2212 cleaved surface (white dots represent the positions of Cu atoms); (d) Theoretical LDOS

Current group members:

The necessary equipment:

+

+

Collaborators:

Thomas A. Maier, ORNL, USA

J.C. Seamus Davis, University of Oxford, England

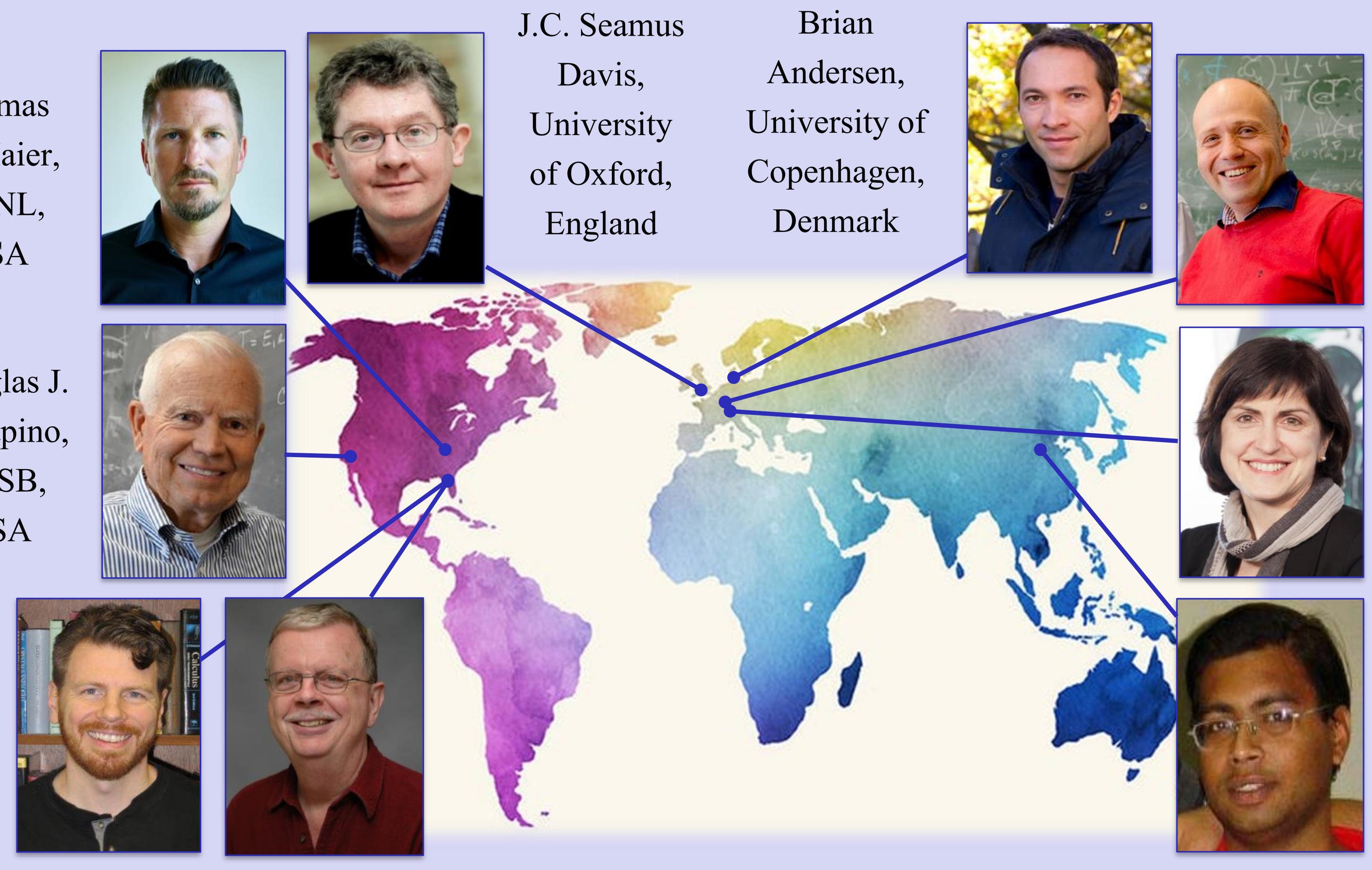
Brian Andersen, University of Copenhagen, Denmark

Ilya Eremin, University of Bochum, Germany

Douglas J. Scalapino, UCSB, USA

Roser M. Valenti, University of Frankfurt, Germany

Vivek Mishra, KITP, CAS, China



James Hamlin & Greg Stewart, UF, USA

Social activities: