The Mechanism of High Temperature Superconductivity – with a pinch of Irony

magnetic hour-glass dispersion a necessary prerequisite for superconductivity in $Fe_{1+y}Te_{0.7}Se_{0.3}$


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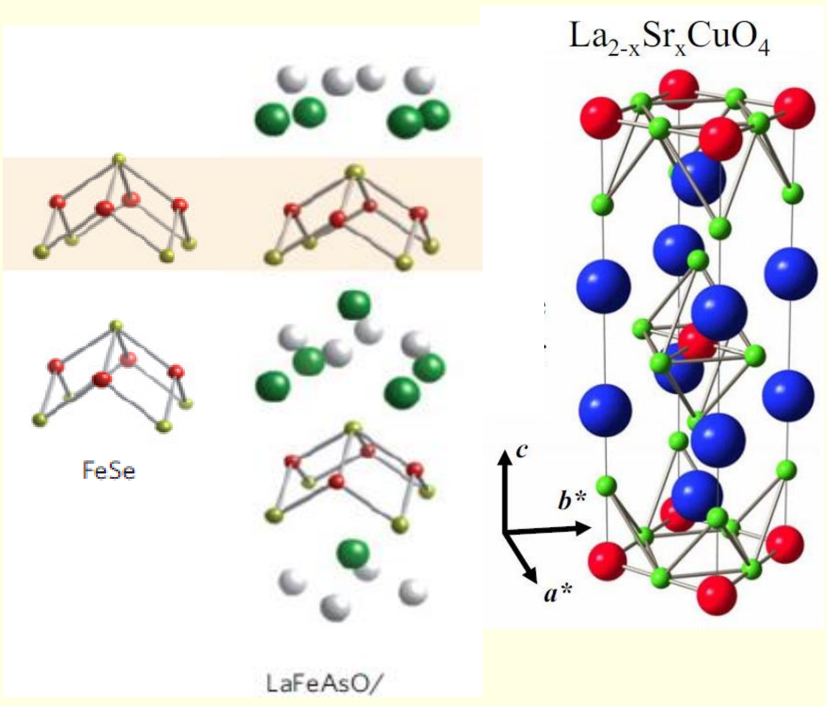
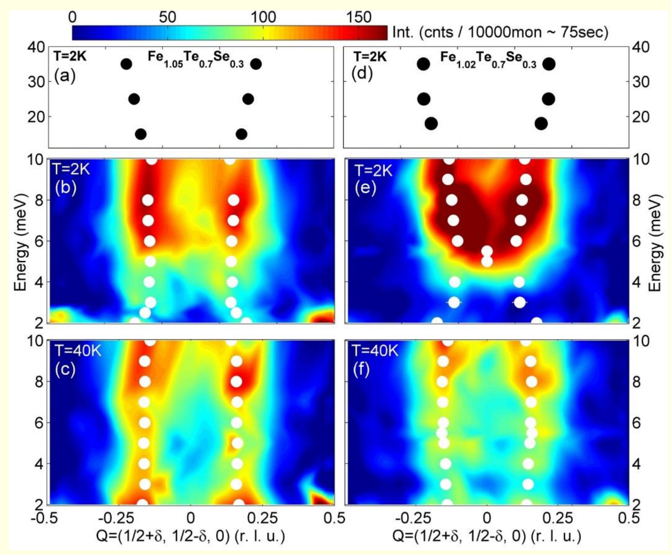
Iron based superconductors and cuprates

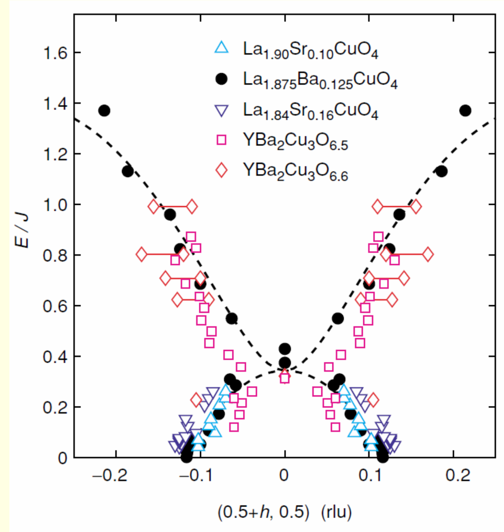
- Some similarities:
  - Layered structure
  - Superconductivity near antiferromagnetic phase
  - …
- But also many differences:
  - Metallic / Mott insulator ceramic
  - Multi-band / single band
  - s±-wave / d-wave
- Within each family there are also differences
  - So lets step back and look for common features



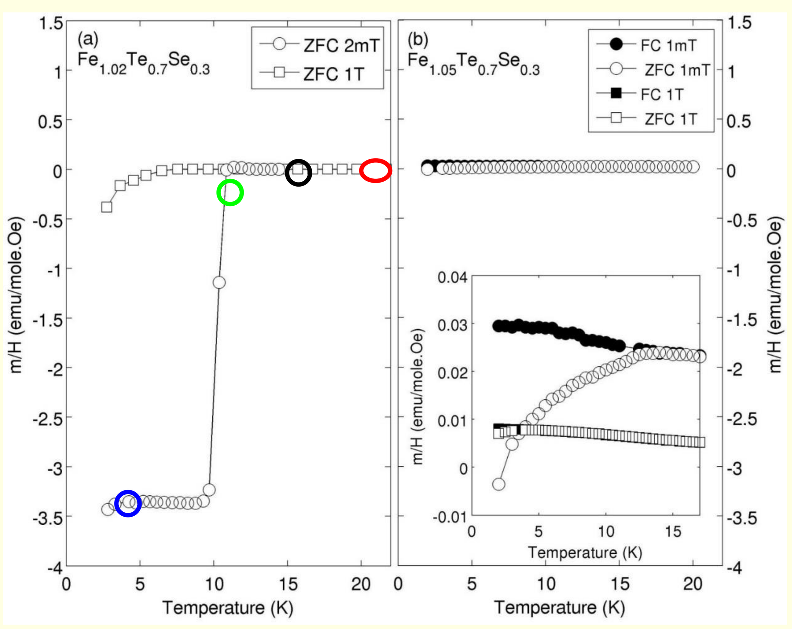
A remarkable common feature

- Our experiments on $Fe_{1+y}Te_{0.7}Se_{0.3}$ reveal hour-glass (HG) dispersion, like in the cuprates (Also reported by several other groups)
  - Hour-glass dispersion is rare in magnetic materials
  - That both high-Tc classes have HG can hardly be a coincidence
  - But does HG cause superconductivity or is it caused by superconductivity?



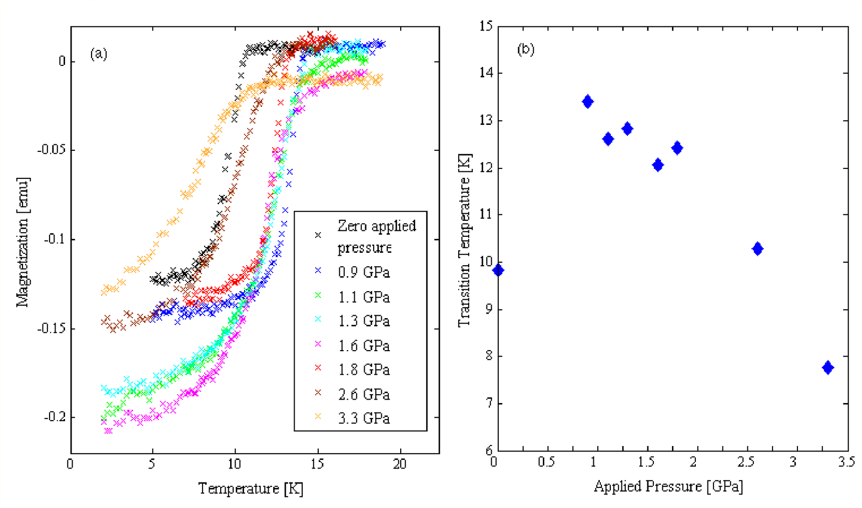


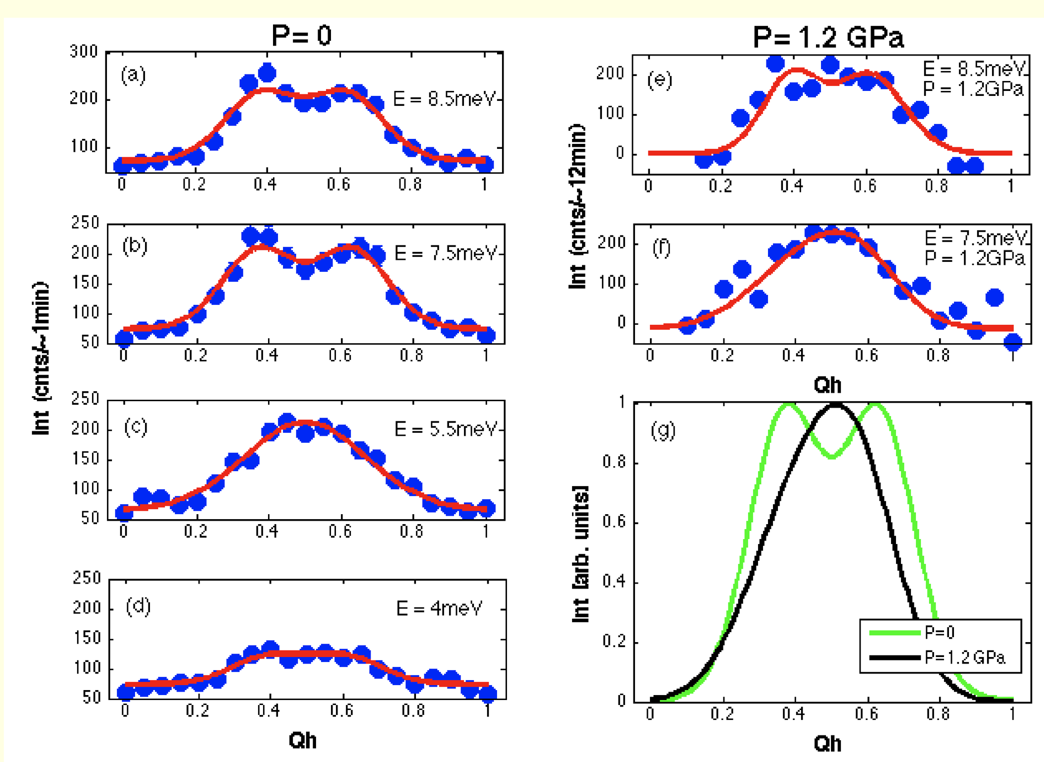
Excess iron switch off SC

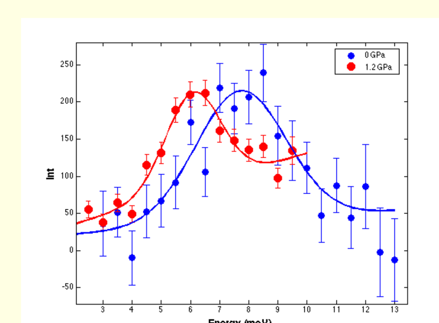


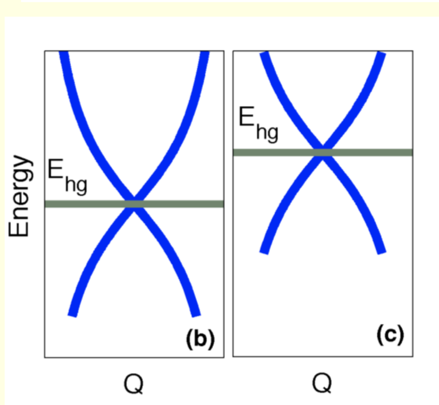
- Controlling excess iron difficult, so keep Te/Se constant and vary Fe
- Both SC and non-SC $Fe_{1+y}Te_{0.7}Se_{0.3}$ show incommensurate excitations
- But, only SC show commensuration to hour-glass shape

Pressure:
Ehg increases ⇒ Tc increases

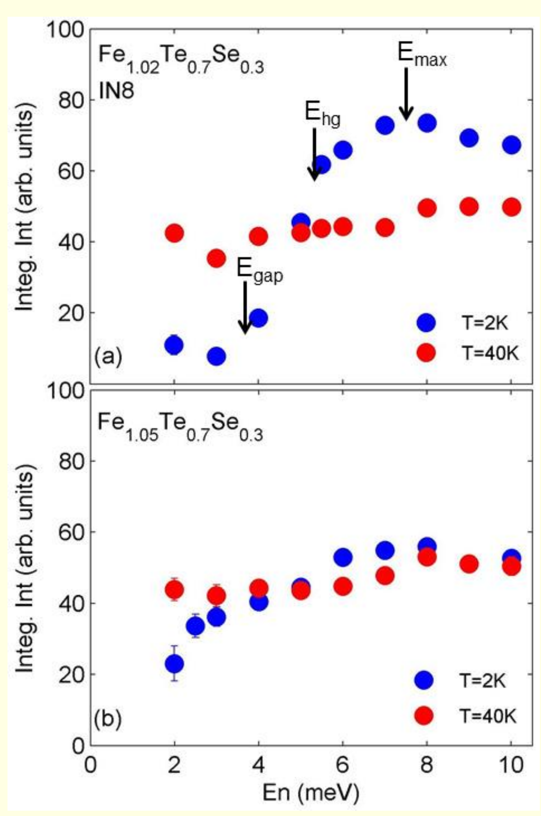




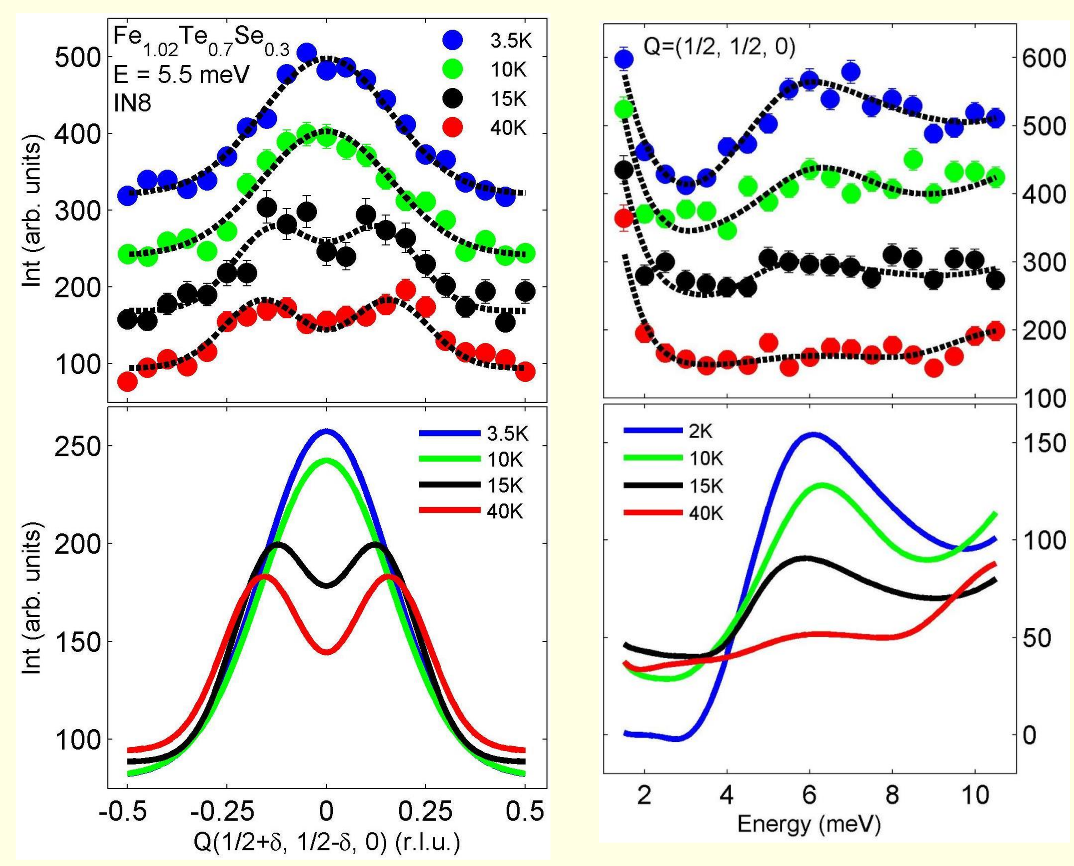




- Need to define 3 energies:
  - E_{hg} the commensuration energy of the hour-glass dispersion
  - E_{gap} the energy below which spectral weight is removed
  - E_{max} the energy where maximum occur when spectral weight is moved to above the gap



Hourglass develop above Tc – Spin-gap below

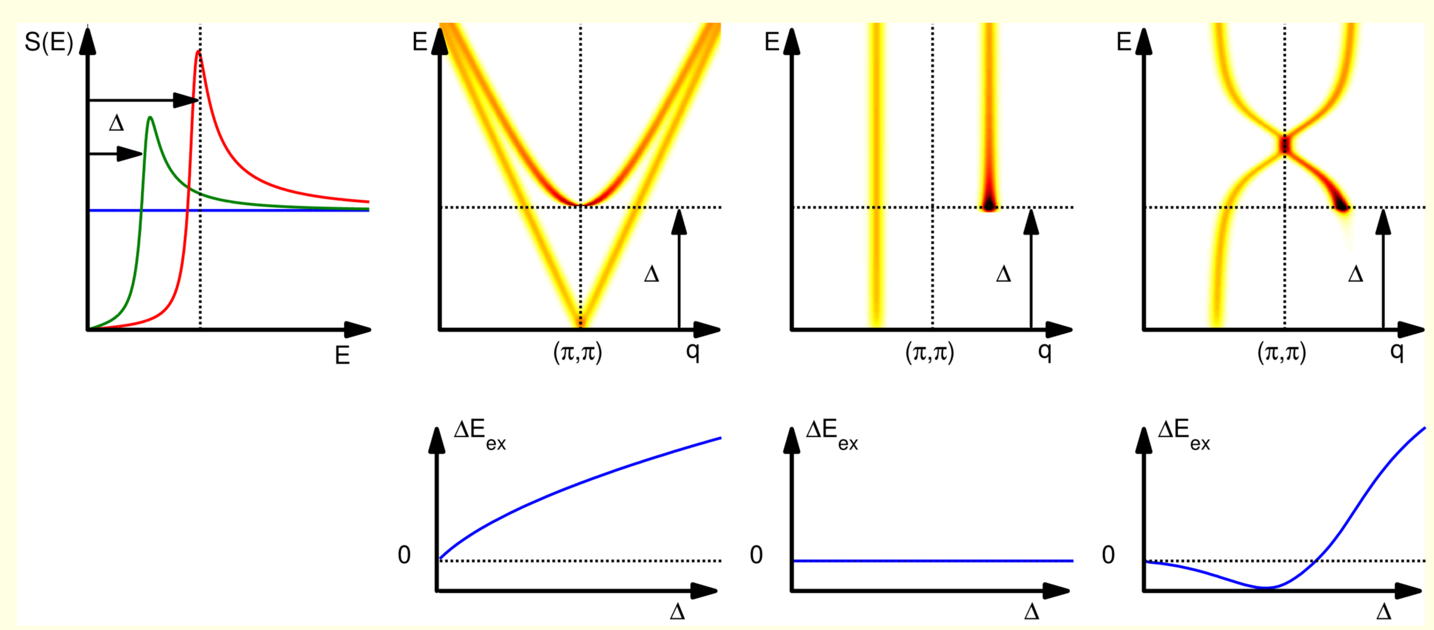


Commensurate pinch necessary condition for SC
  y=0.05: no pinch ⇔ no SC
  y=0.02: pinch develop above T_c, T_c sets in when pinch 'complete'

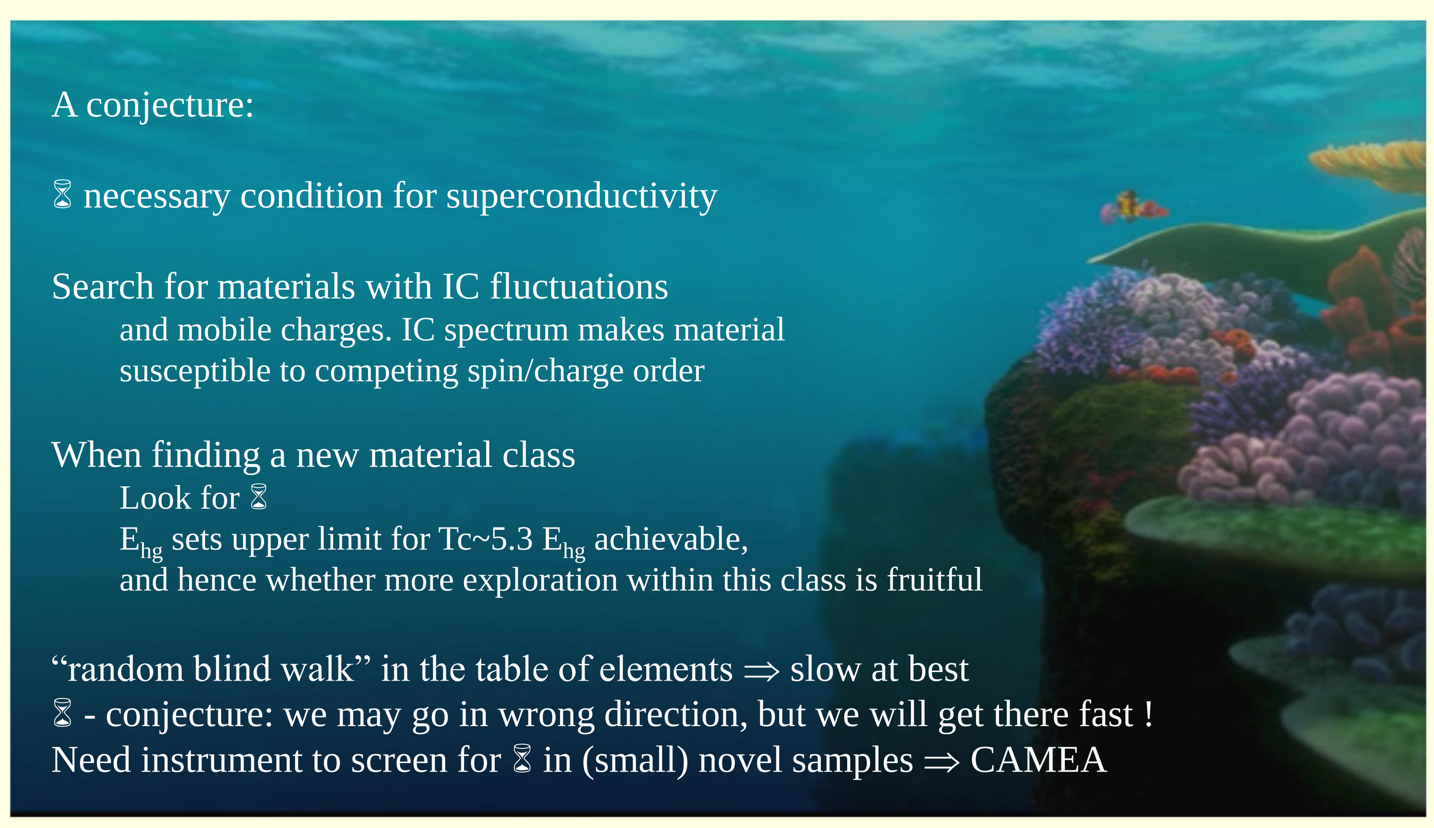
Spin gap is consequence of SC
  Spin gap directly linked to SC gap

Mechanism of SC – gain in magnetic exchange energy?

$$\langle \mathbf{S}_i \cdot \mathbf{S}_j \rangle = 3J \int \frac{d\omega}{\pi} \int \frac{d2q}{(2\pi)^2} S(\mathbf{q},\omega)(\cos(q_x) + cos(q_y))$$



How to discover a new superconductor



A conjecture:

⌛ necessary condition for superconductivity

Search for materials with IC fluctuations
  and mobile charges. IC spectrum makes material
  susceptible to competing spin/charge order

When finding a new material class
  Look for ⌛
  E_{hg} sets upper limit for Tc~5.3 E_{hg} achievable,
  and hence whether more exploration within this class is fruitful

"random blind walk" in the table of elements ⇒ slow at best
⌛ - conjecture: we may go in wrong direction, but we will get there fast !
Need instrument to screen for ⌛ in (small) novel samples ⇒ CAMEA

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