

Non Fermi Liquids: Theory and Experiment.

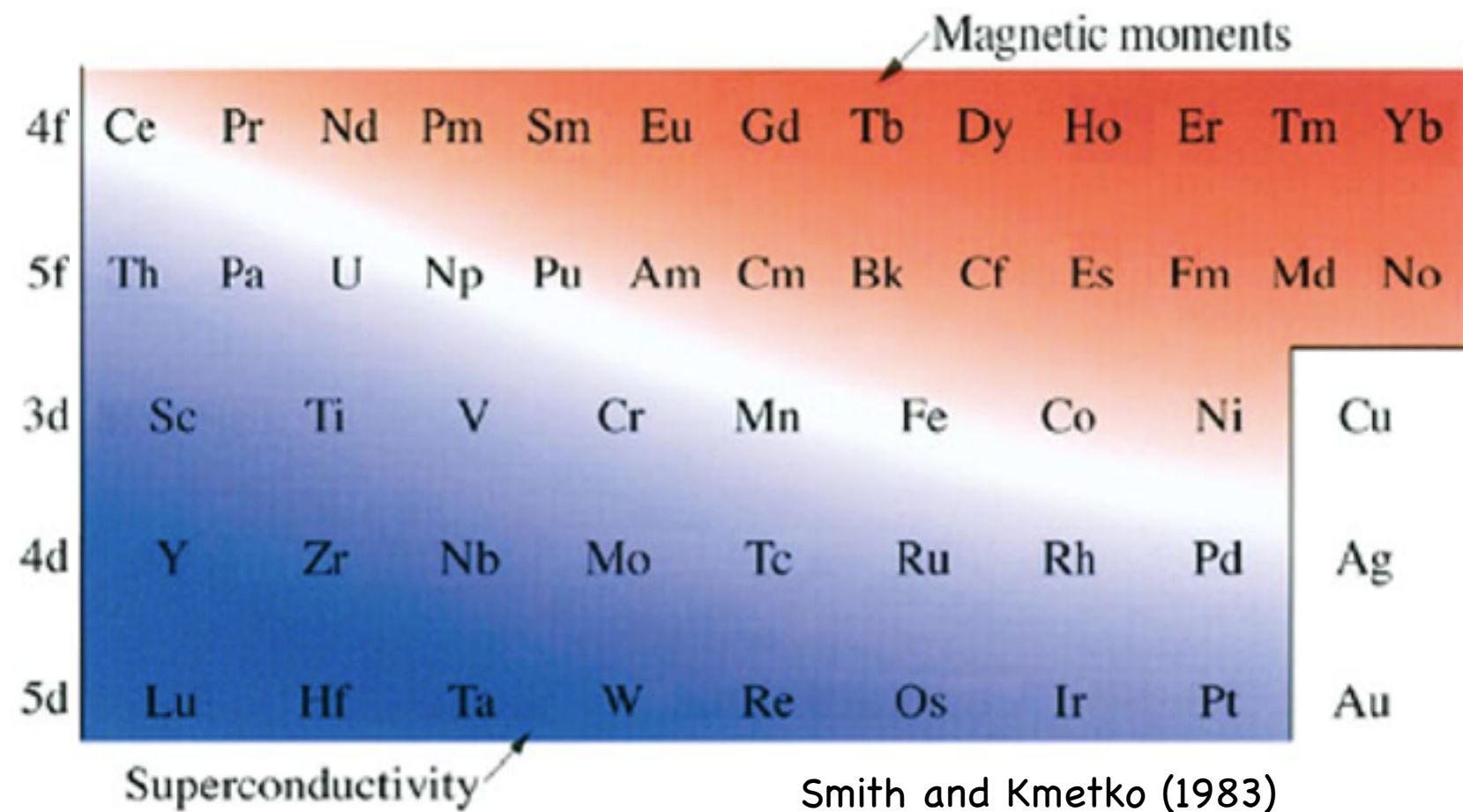
Challenges of understanding Critical and Normal Heavy Fermion Fluids

8.00 - 8.15 am	Piers Coleman (Rutgers University)	Challenges of Understanding Critical and Normal Heavy Fermion Fluids Show abstract
8.15 - 8.50	Collin Broholm (Johns Hopkins University)	The magnetism of strongly correlated metals Show abstract
8.50 - 9.25	Y. Matsumoto (ISSP, University of Tokyo)	Valence fluctuation and strange metal phase in YbAlB ₄ Show abstract
9.25 - 9.45	Coffee break	
9.50 - 10.25	J. D. Thompson (Los Alamos National Laboratory)	Non-Fermi Liquid Behaviors in CeRhIn ₅ and CeCoIn ₅ Show abstract
10.25 - 11.00	A. Yazdani (Princeton University)	Visualizing the Emergence of Heavy Fermions, their Superconductivity, and Hidden Orders with STM Show abstract

Piers Coleman
Center for Materials Theory
Rutgers, USA

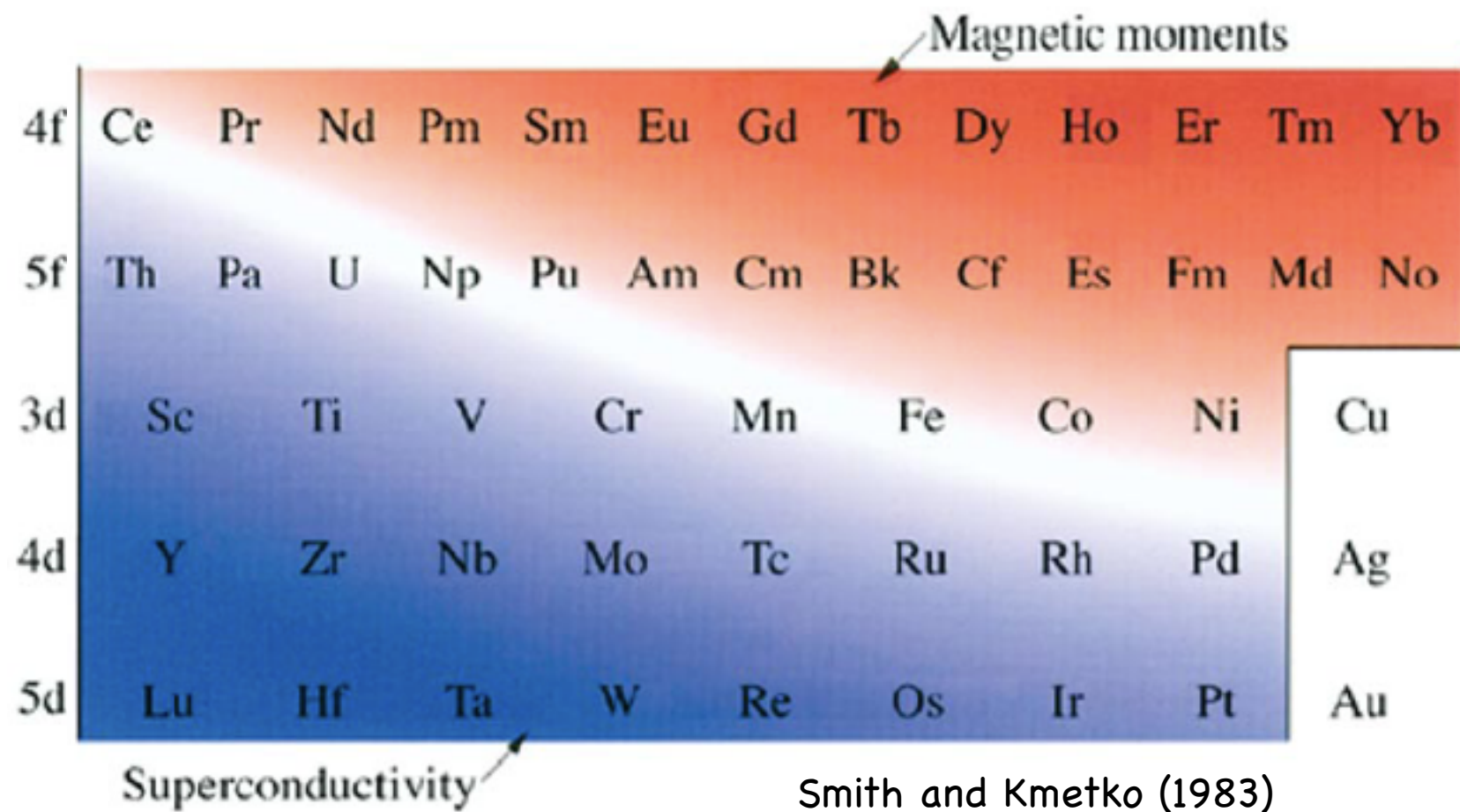


Kmetko-Smith Phase Diagram

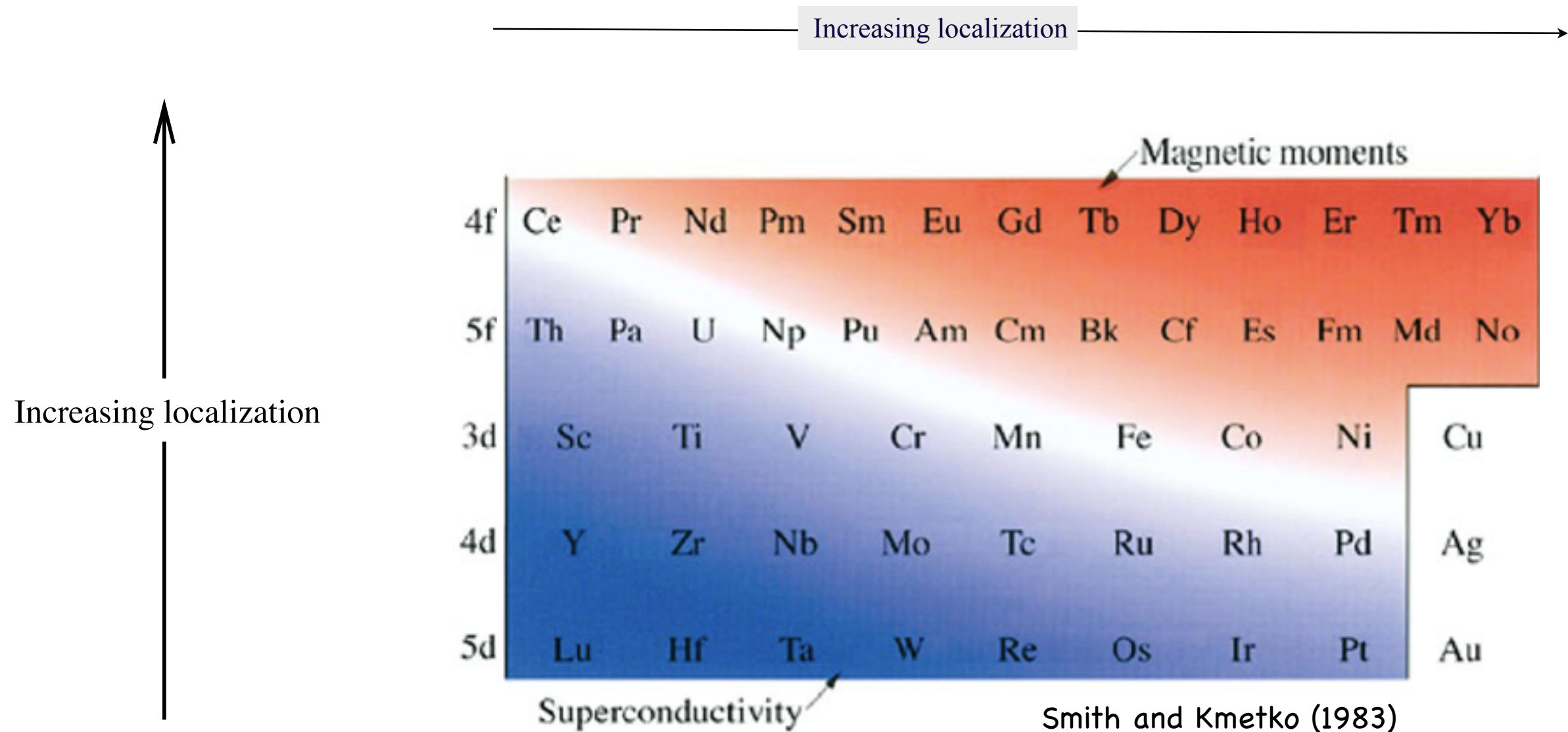


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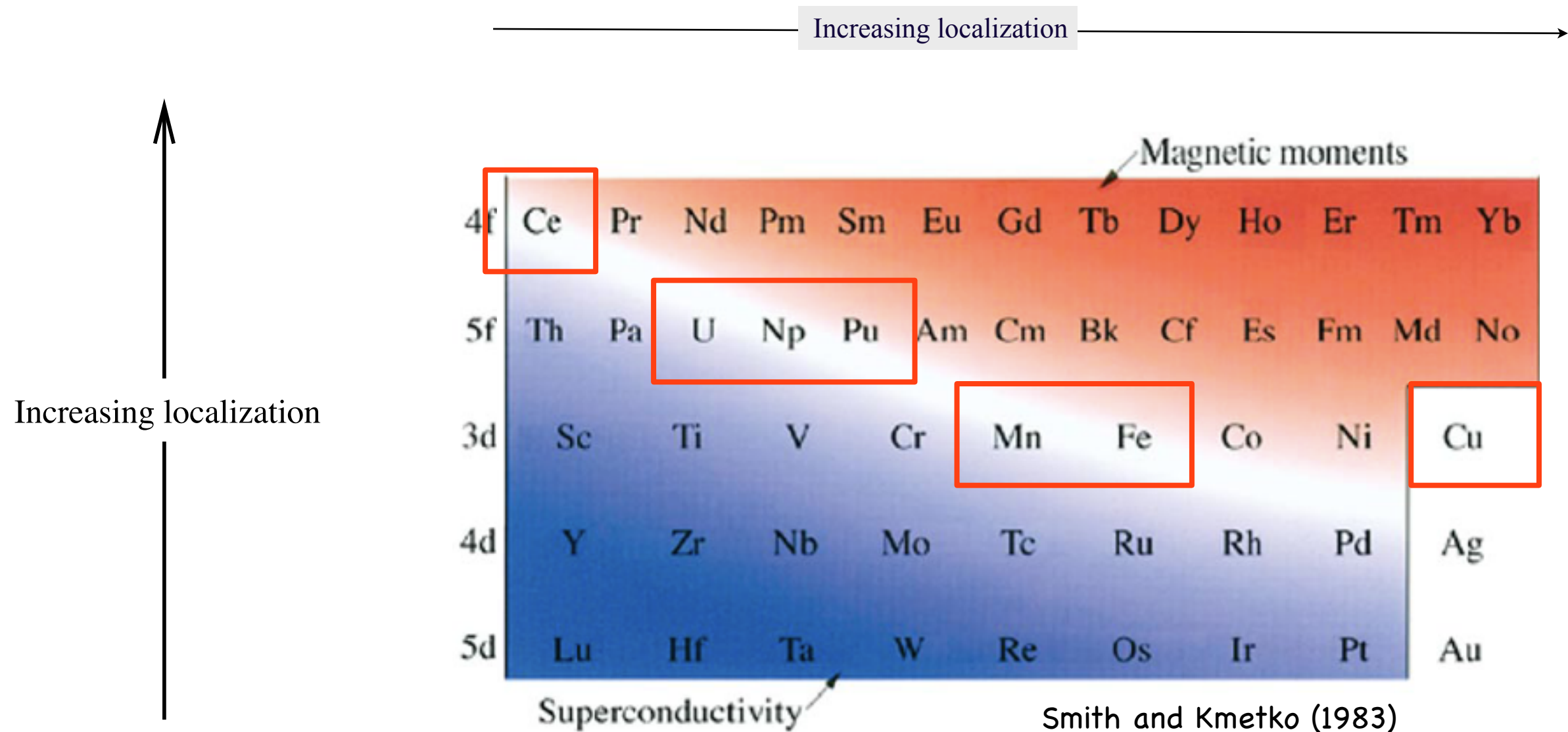
↑
Increasing localization



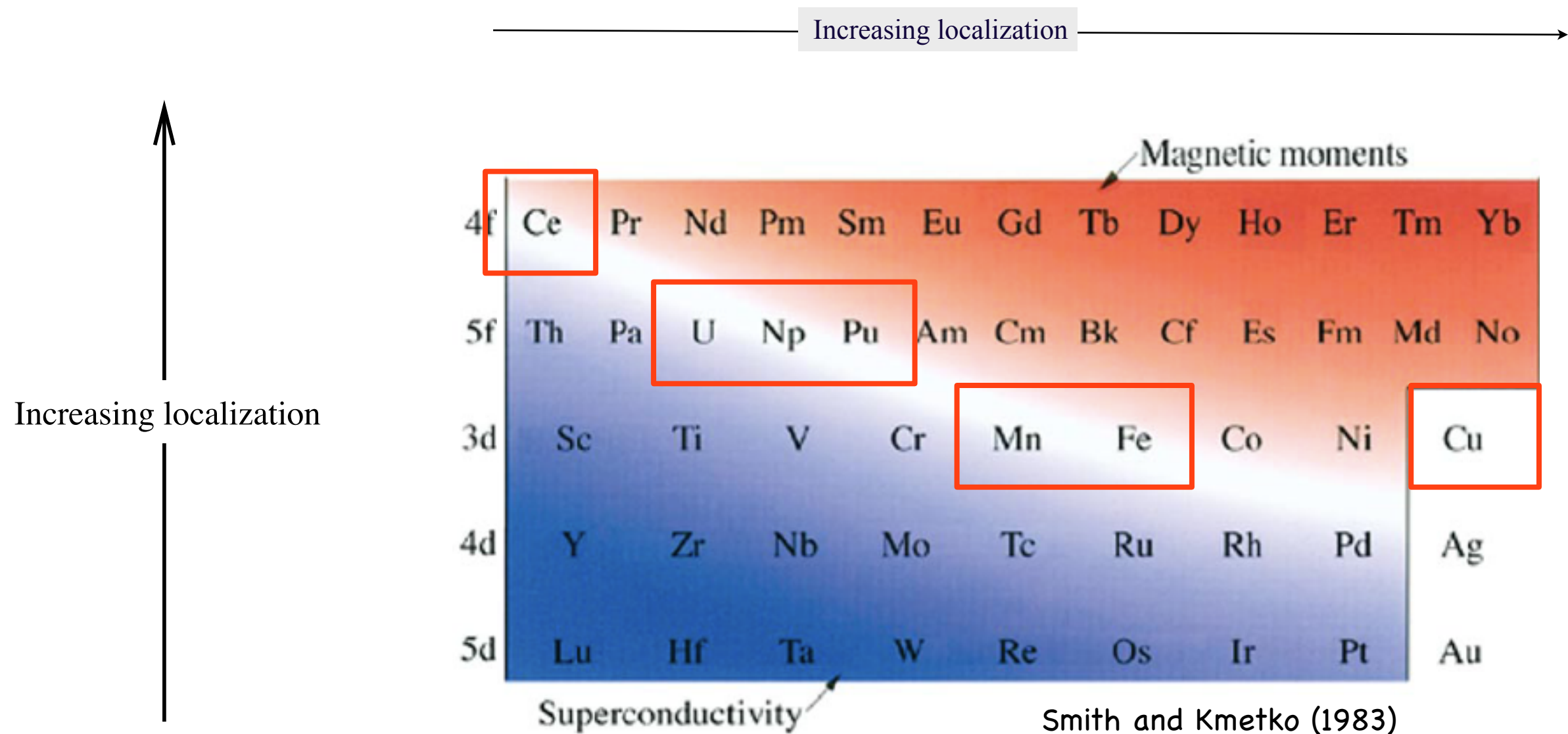
Kmetko-Smith Phase Diagram



Kmetko-Smith Phase Diagram

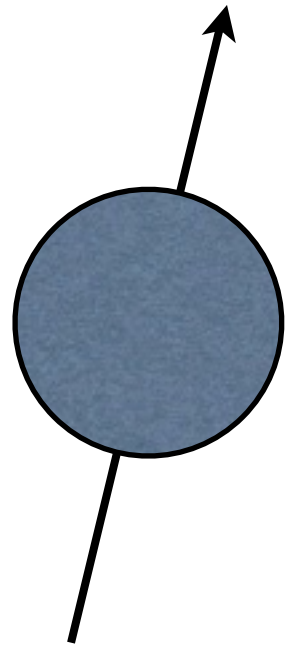


Kmetko-Smith Phase Diagram



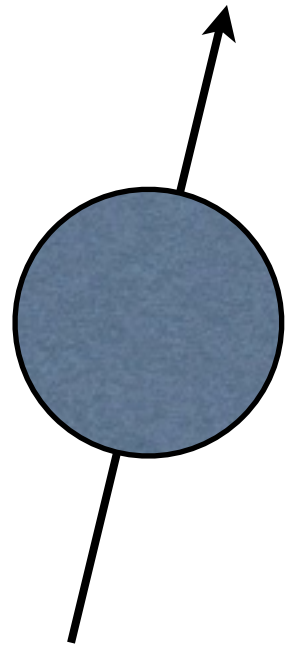
A lot of action at the brink of localization.

Heavy Fermion Primer

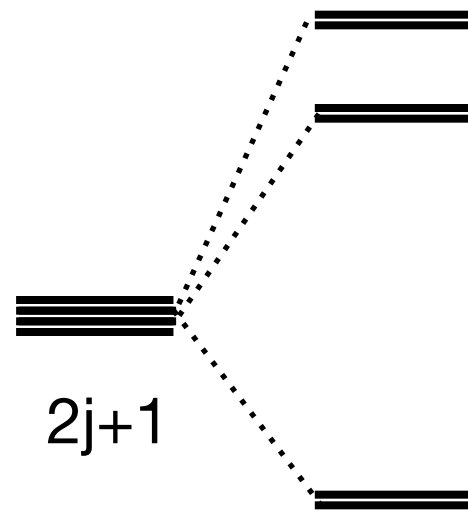


Spin (4f,5f): basic
fabric of heavy
electron physics.

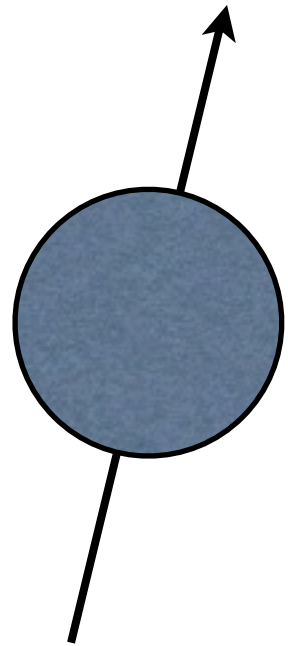
Heavy Fermion Primer



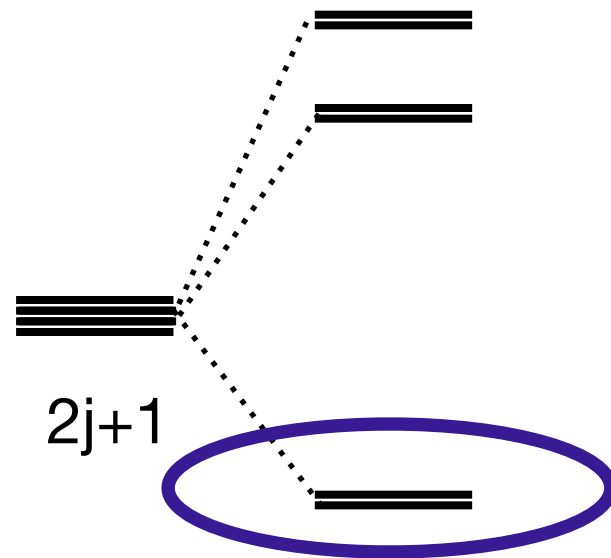
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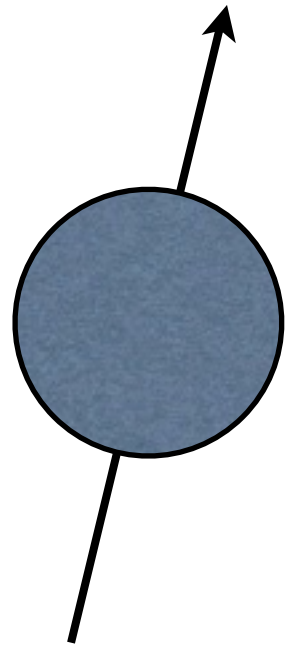
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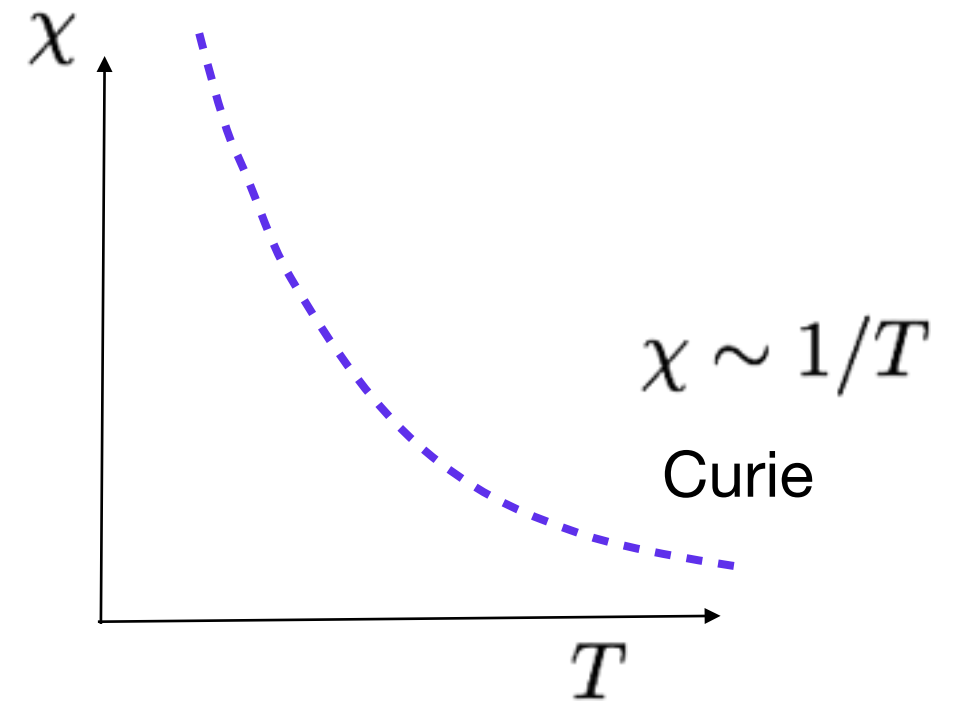
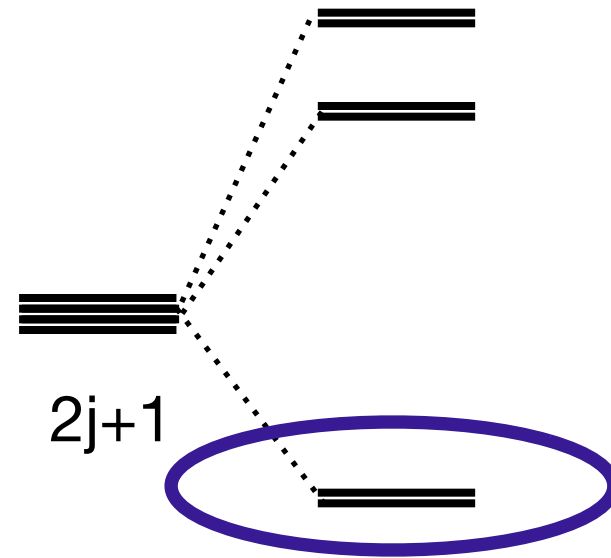
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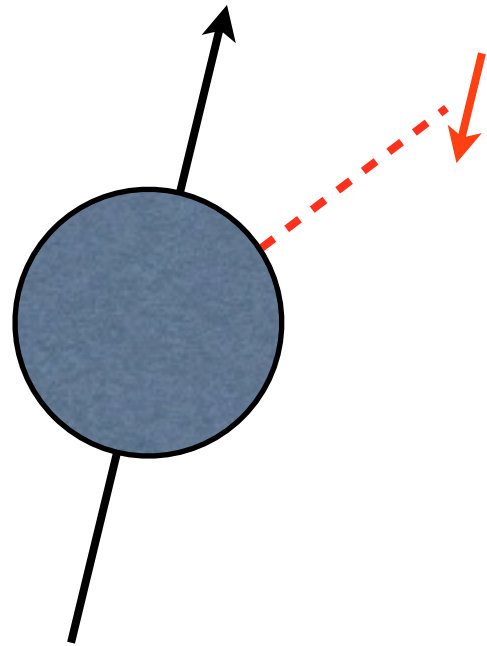
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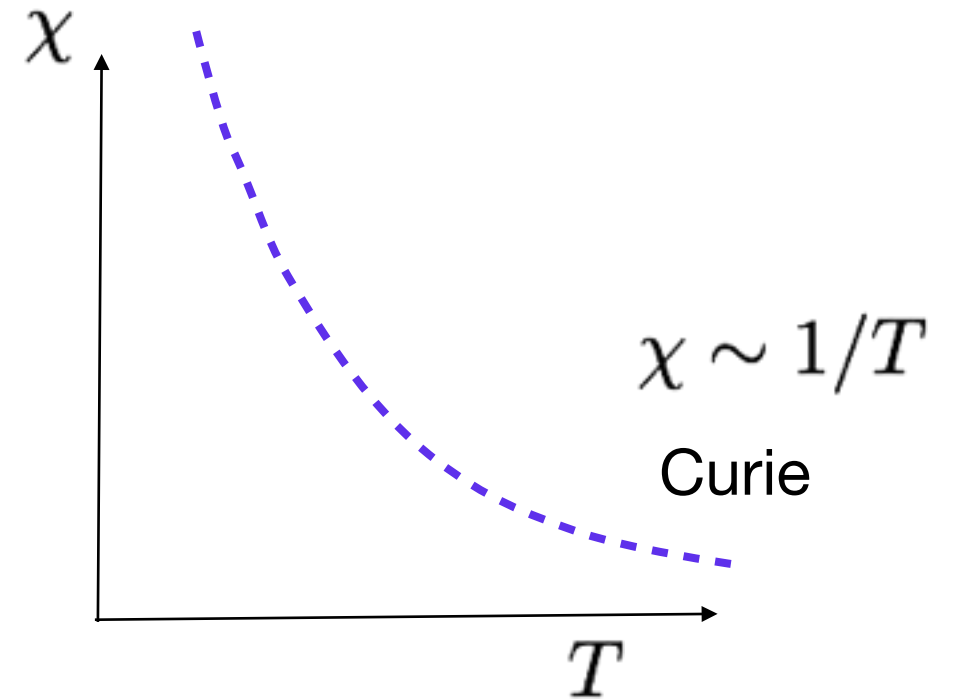
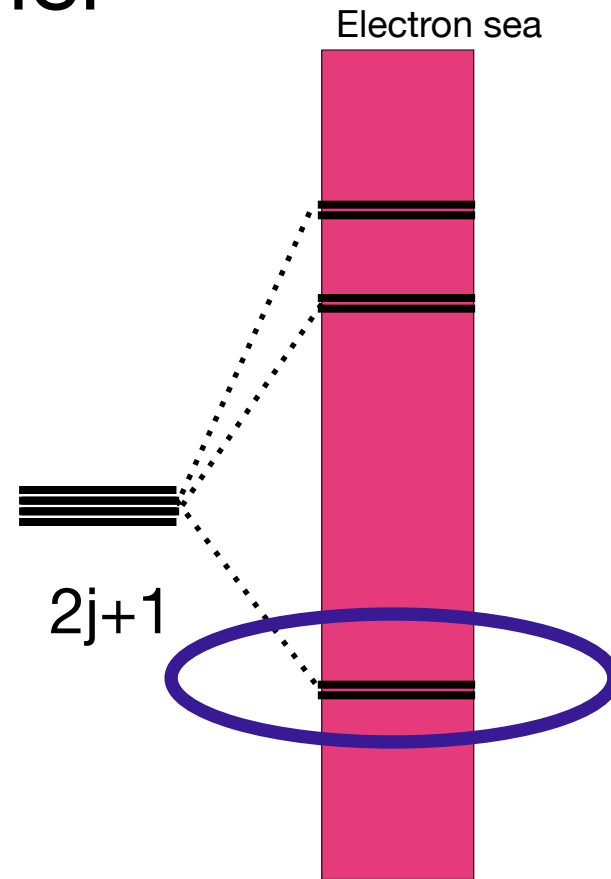
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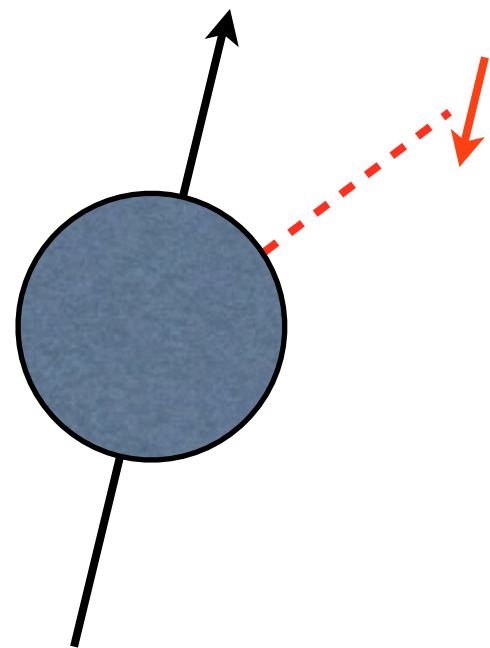


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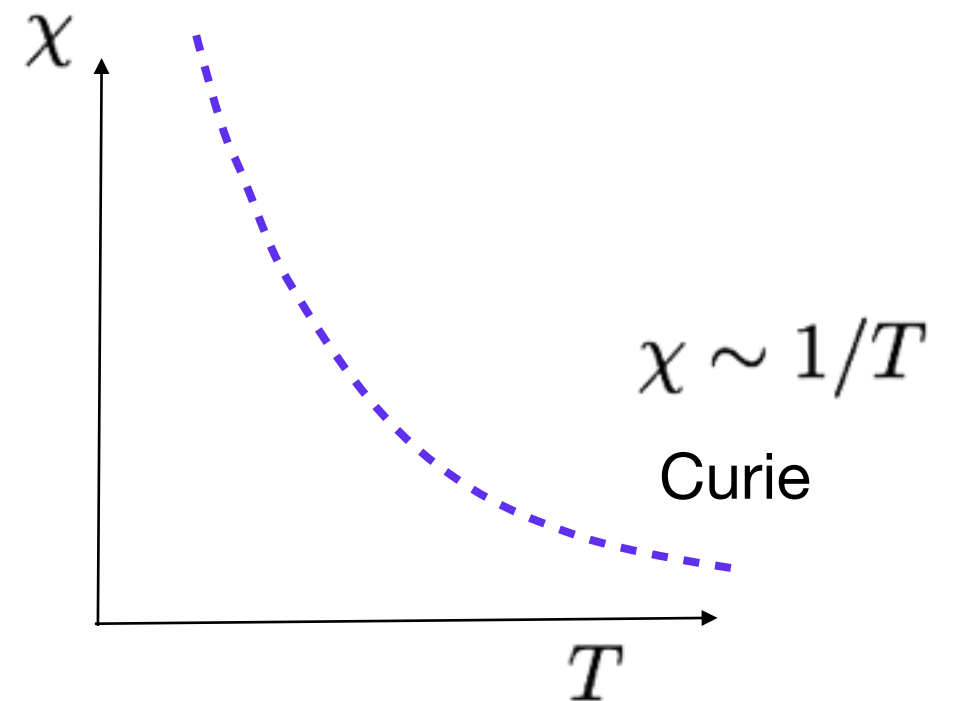
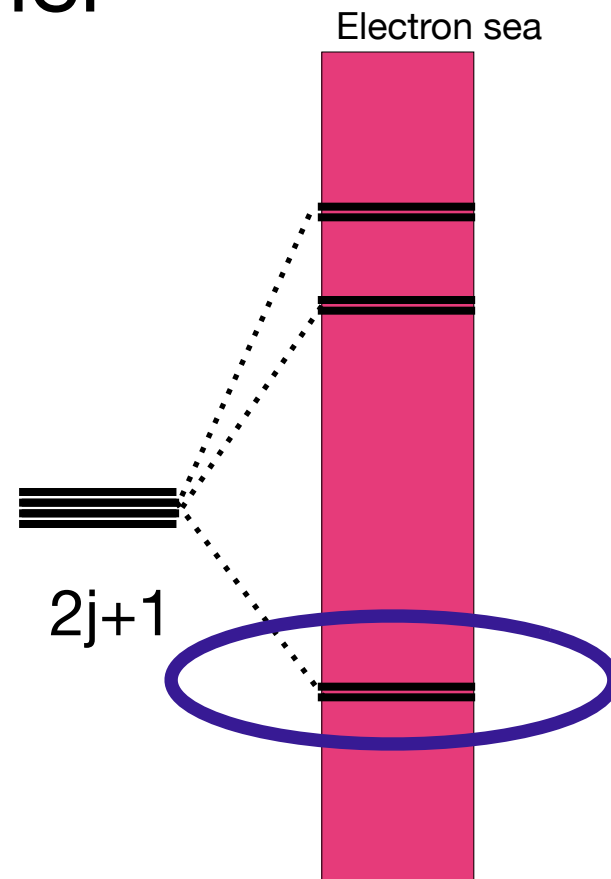


$$H = \sum_{\mathbf{k}\sigma} \epsilon_{\mathbf{k}} c_{\mathbf{k}\sigma}^{\dagger} c_{\mathbf{k}\sigma} + J \vec{S} \cdot \vec{\sigma}(0)$$

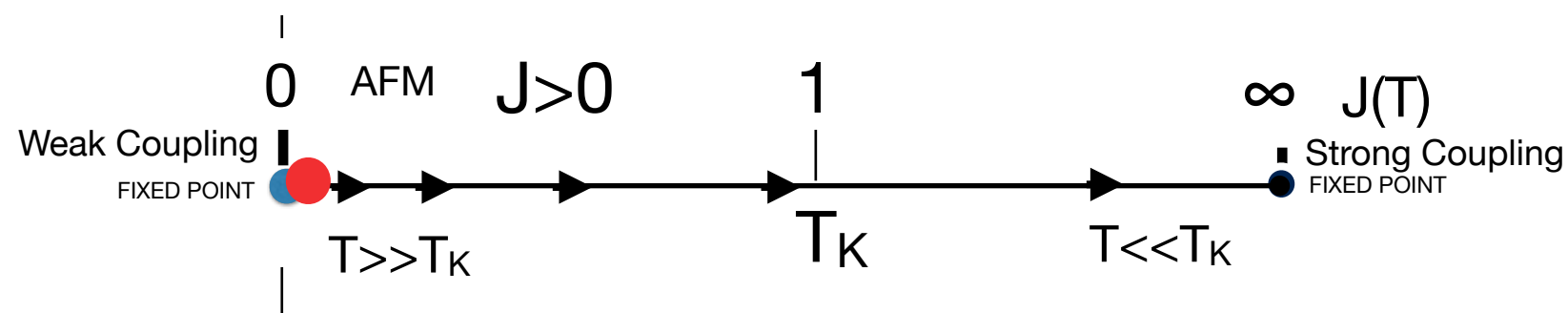
Heavy Fermion Primer



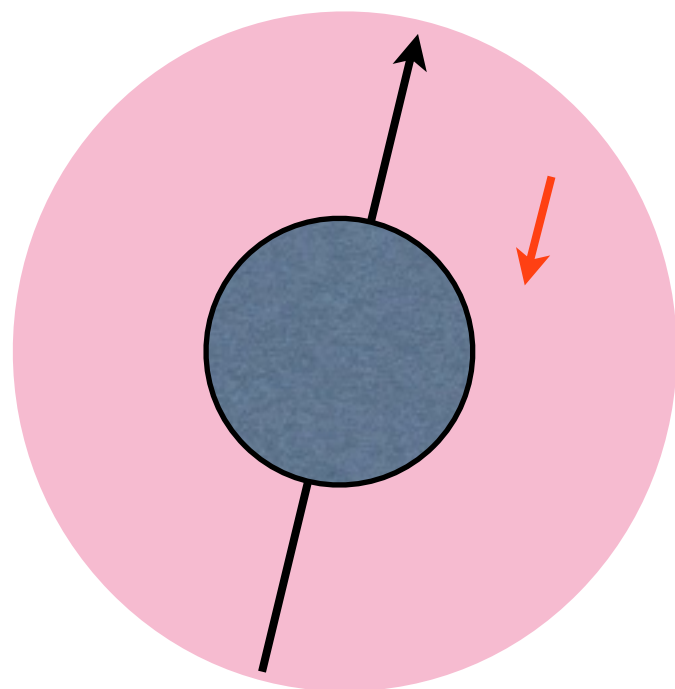
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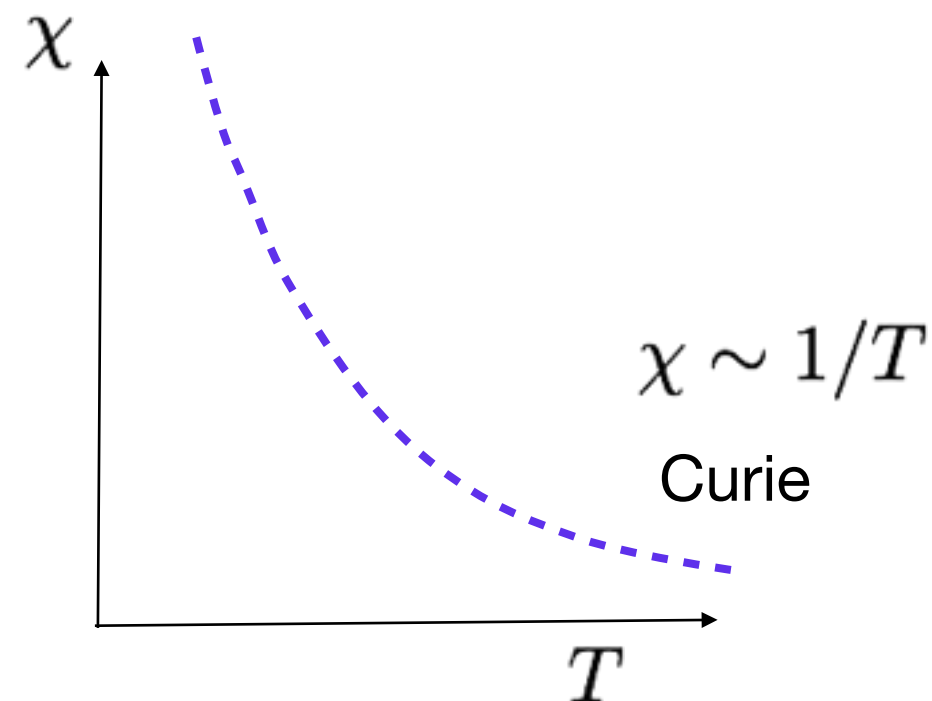
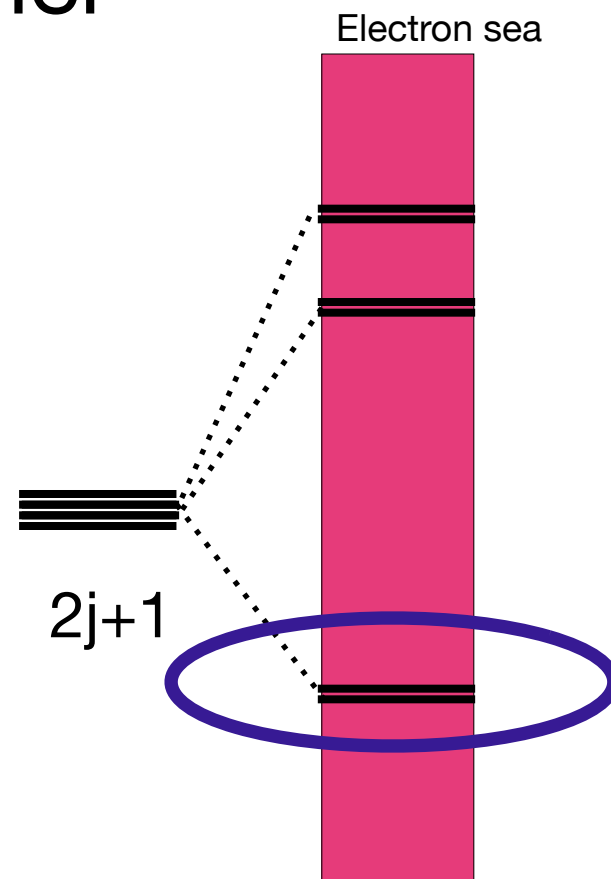
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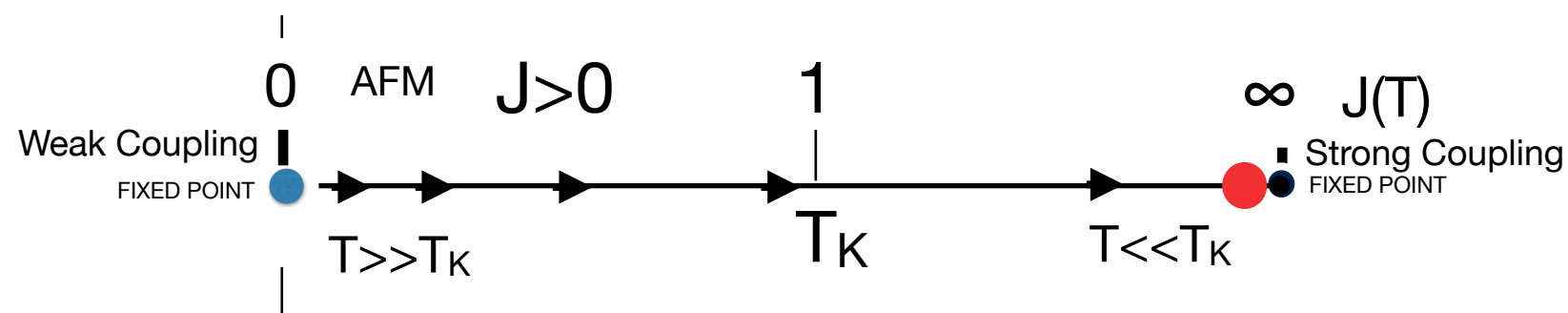
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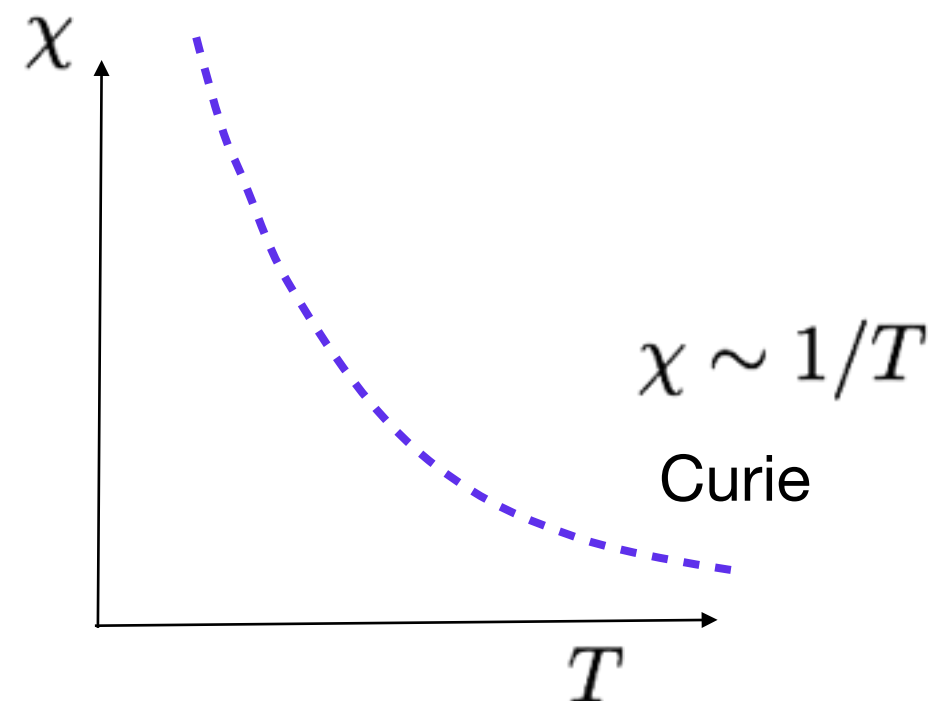
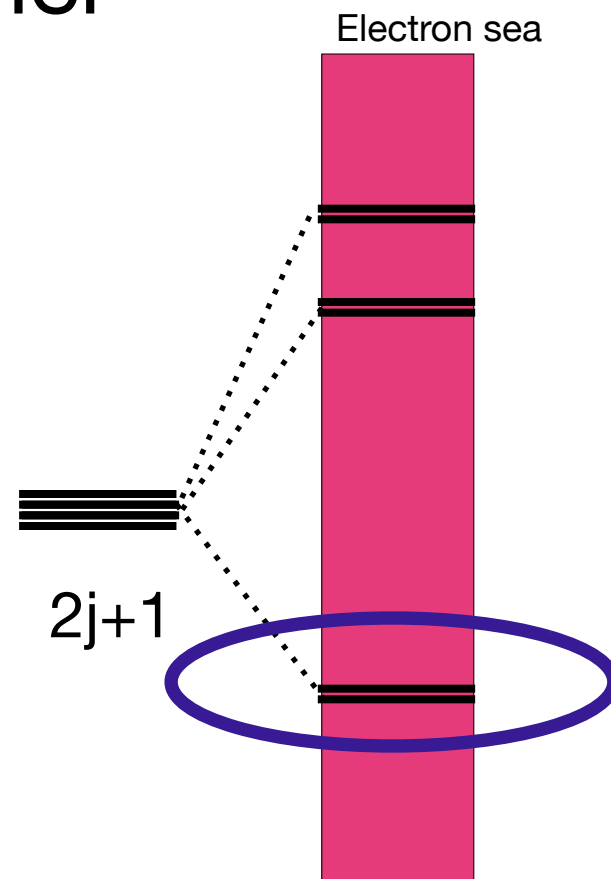
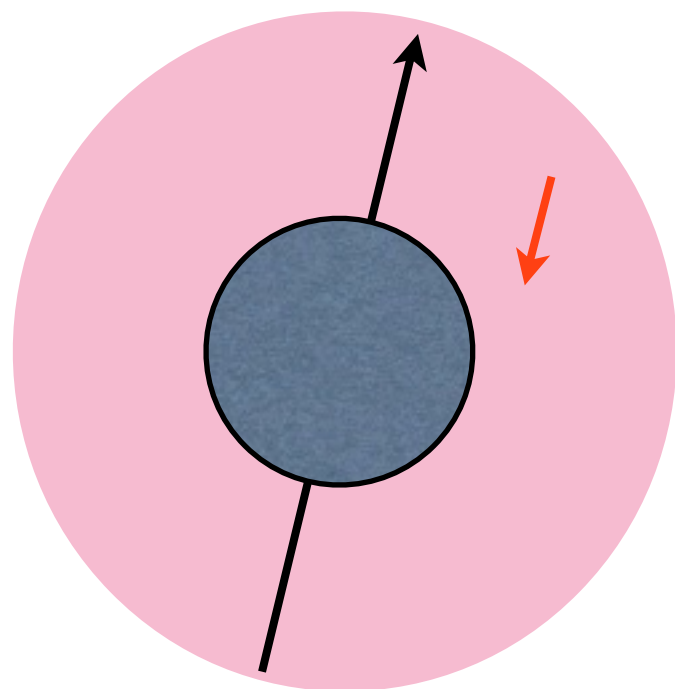
Spin screened by
conduction
electrons: entangled



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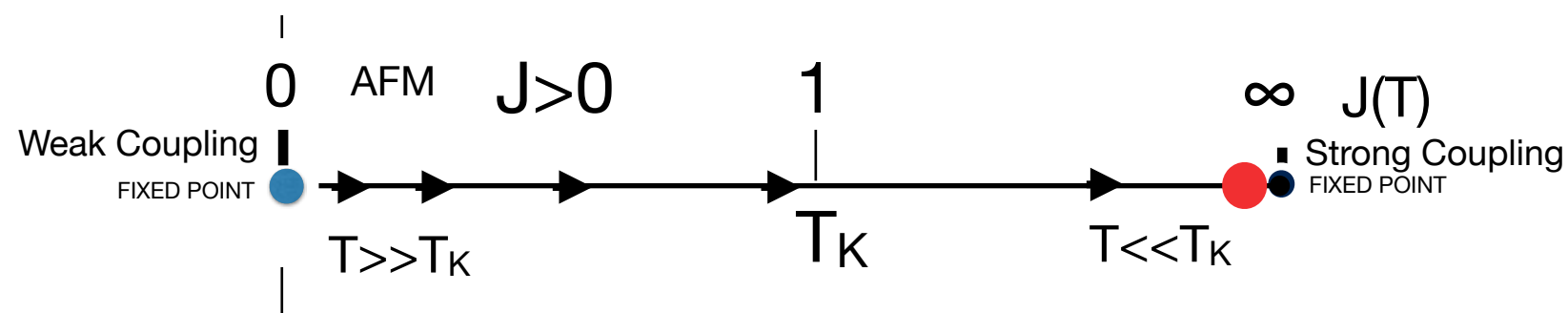
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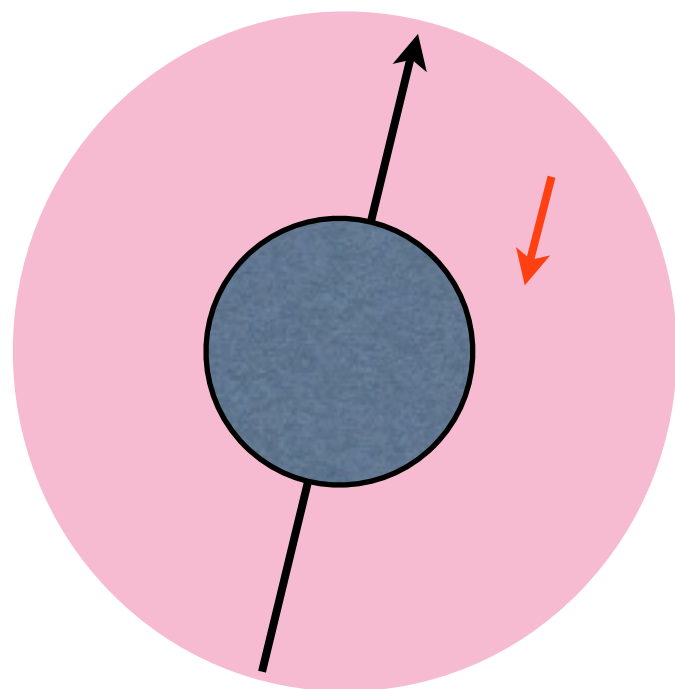
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↑ ↓ − ↓ ↑

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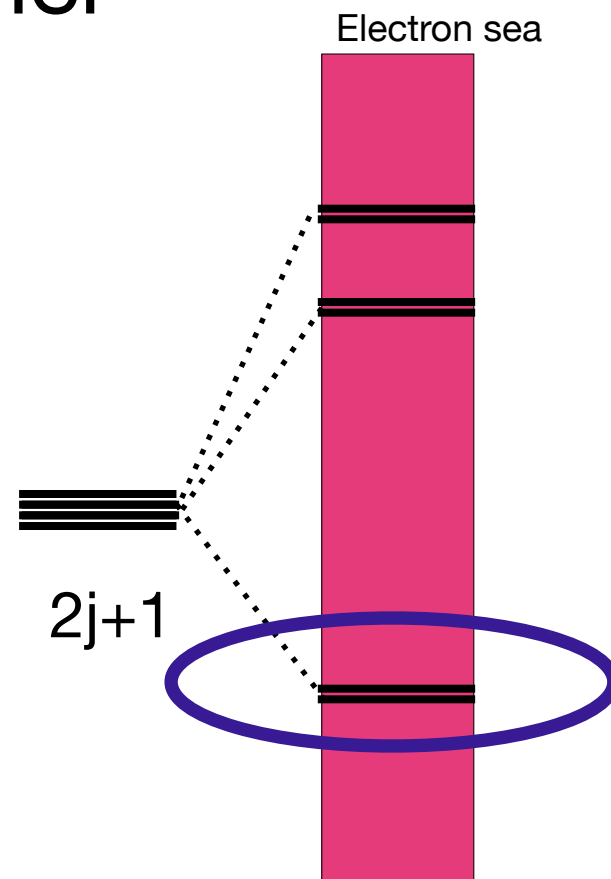


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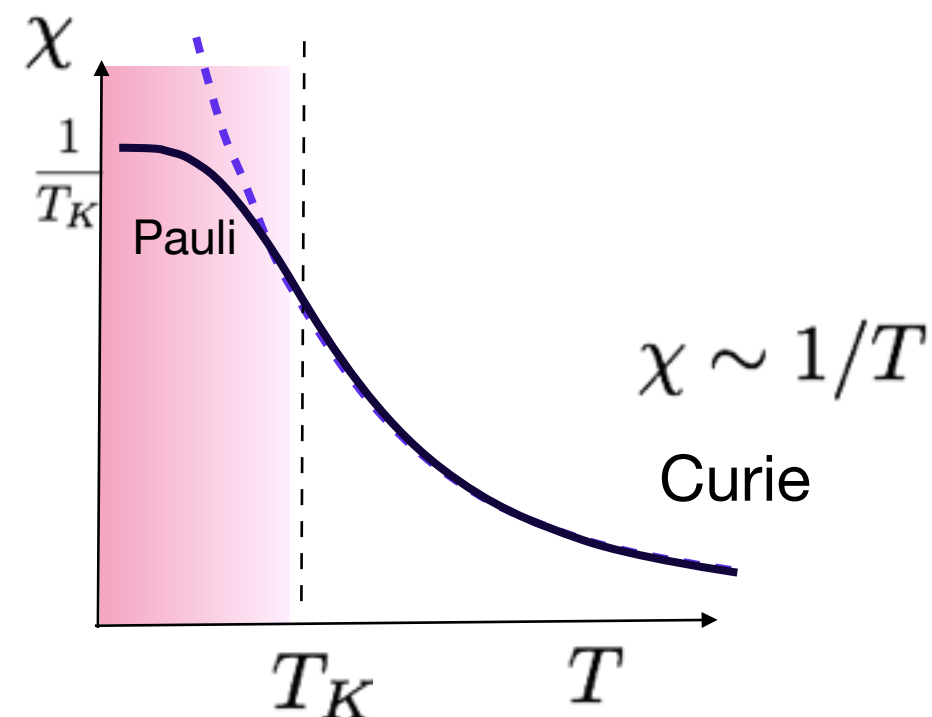
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$\uparrow \downarrow - \downarrow \uparrow$

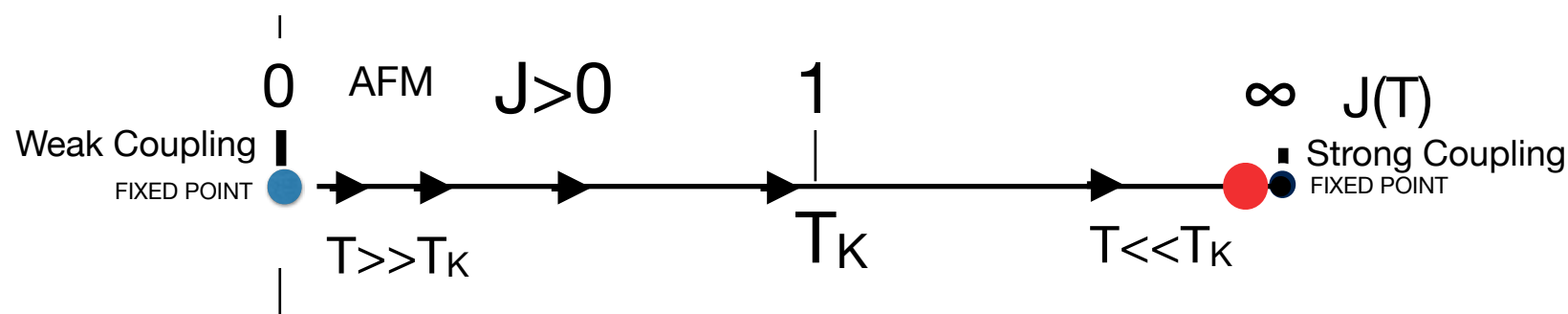


$$T_K \sim D e^{-\frac{1}{2J\rho}}$$

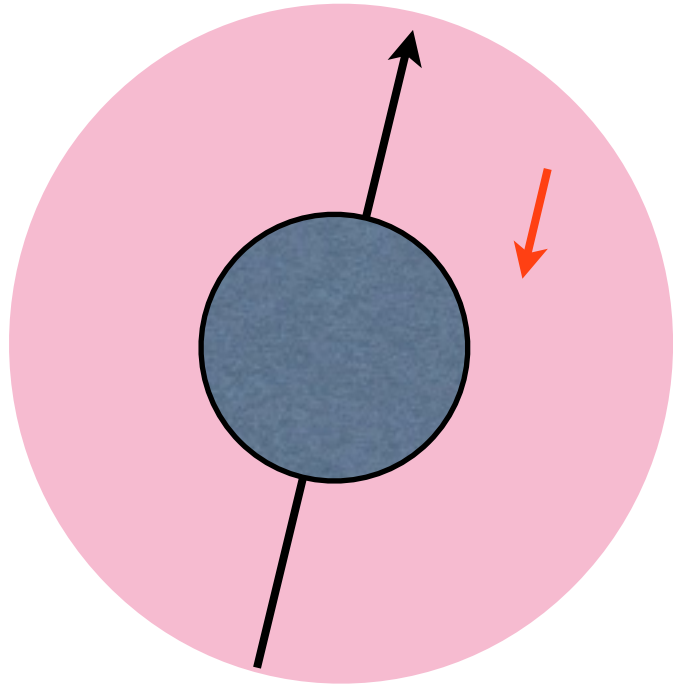
“Kondo temperature”



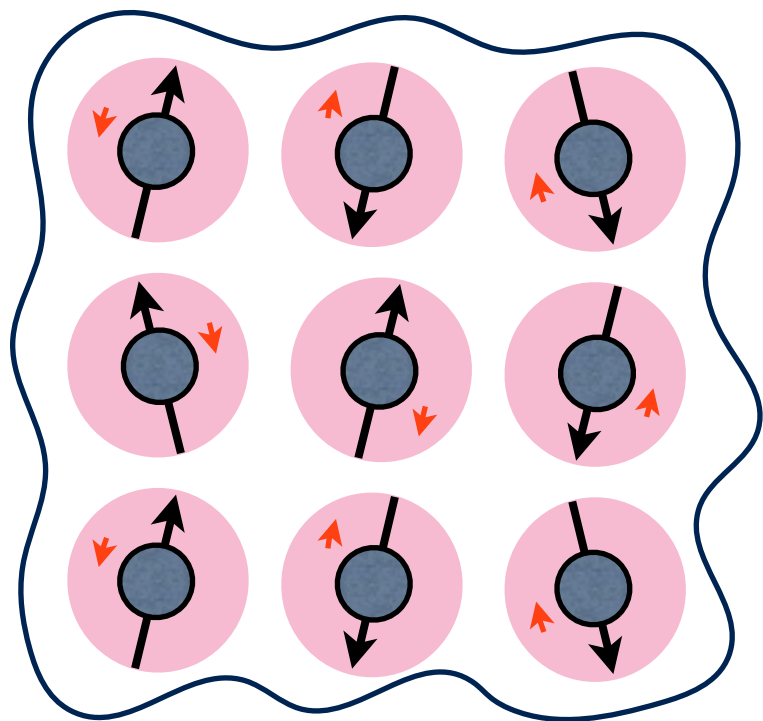
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Heavy Fermion Primer

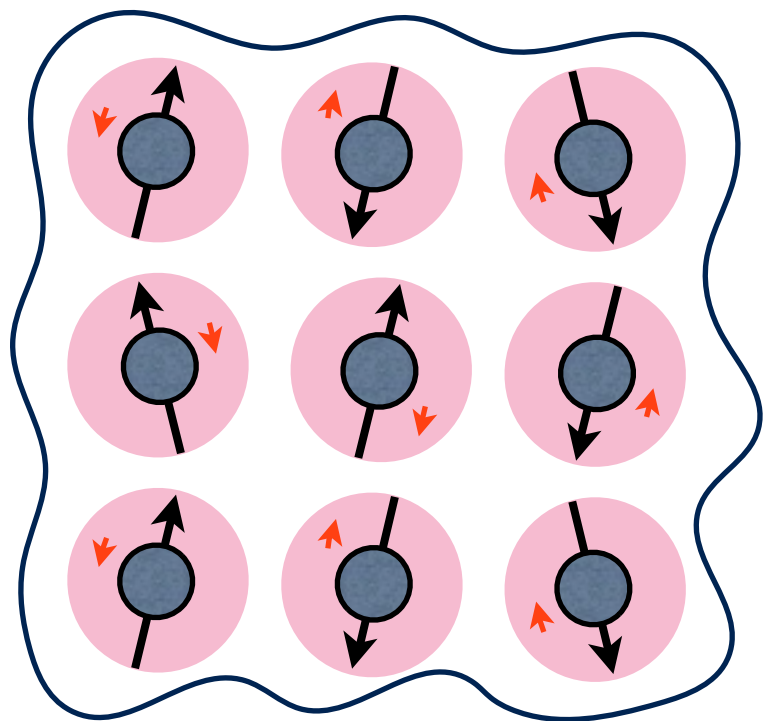


Heavy Fermion Primer



“Kondo Lattice”

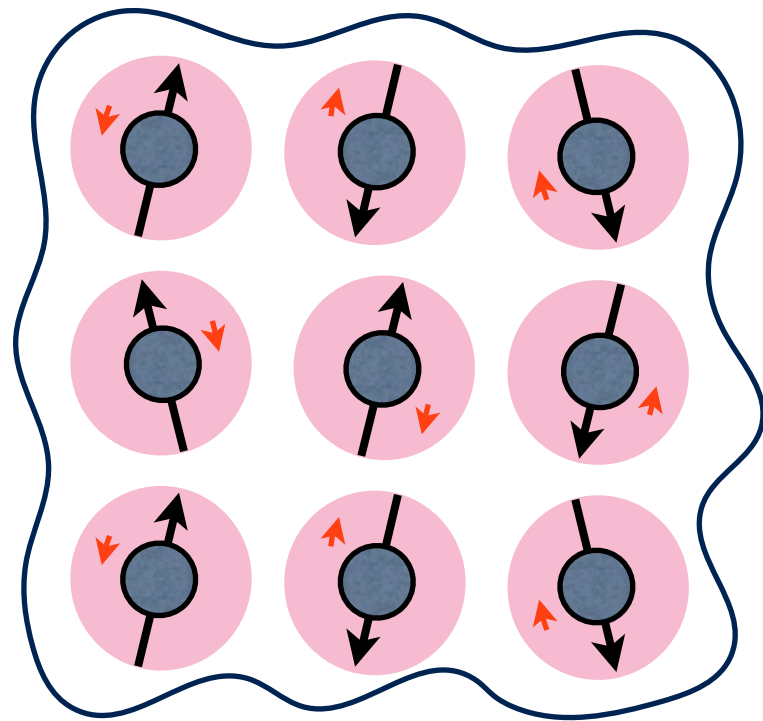
Kondo Insulators



“Kondo Lattice”

Entangled many body state of spins and electrons gives rise to many new kinds of order.

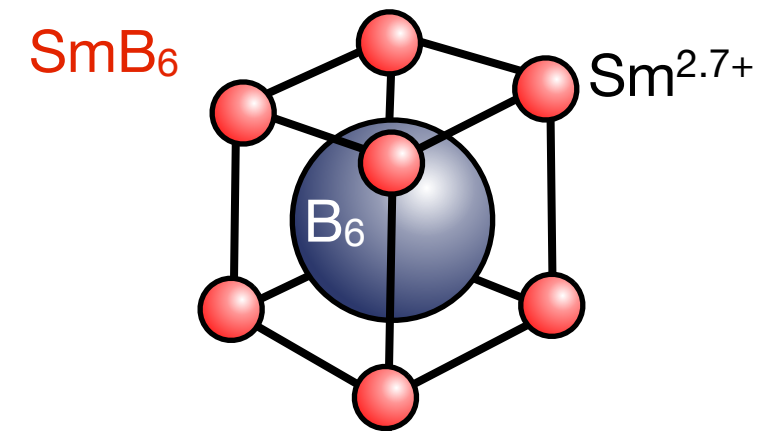
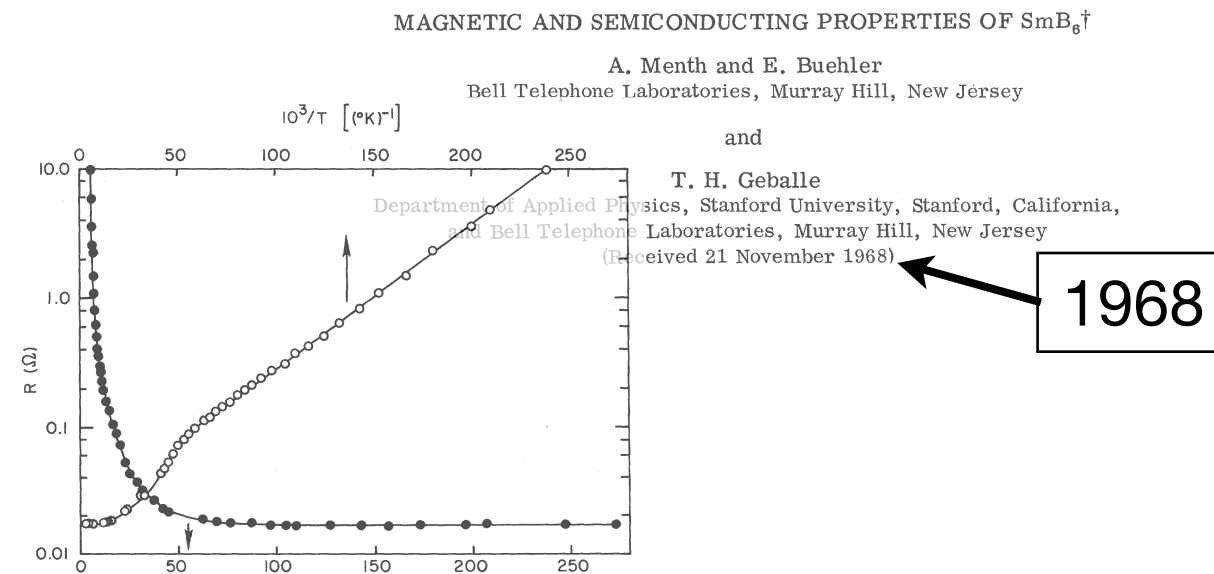
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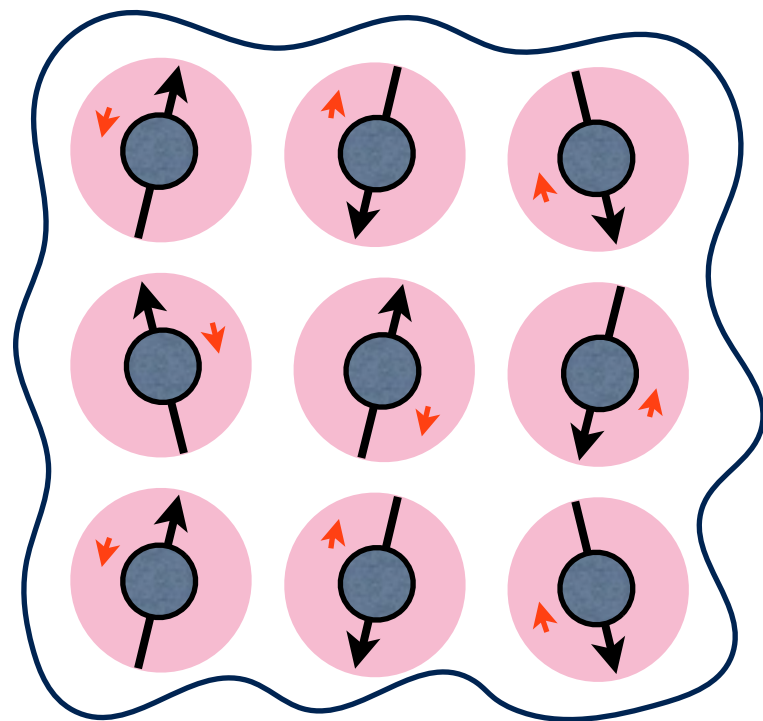
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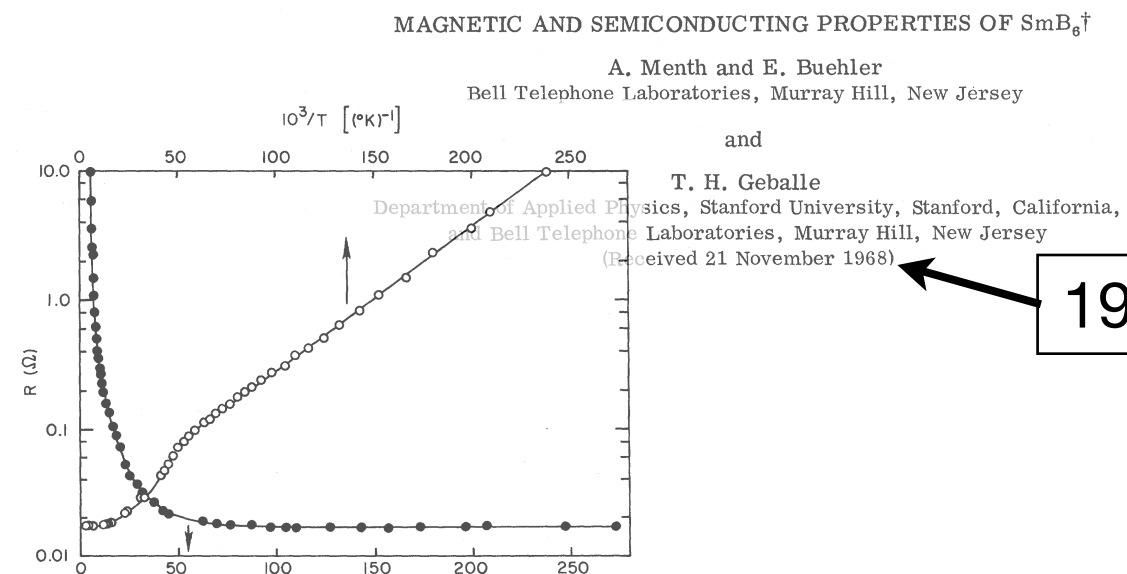
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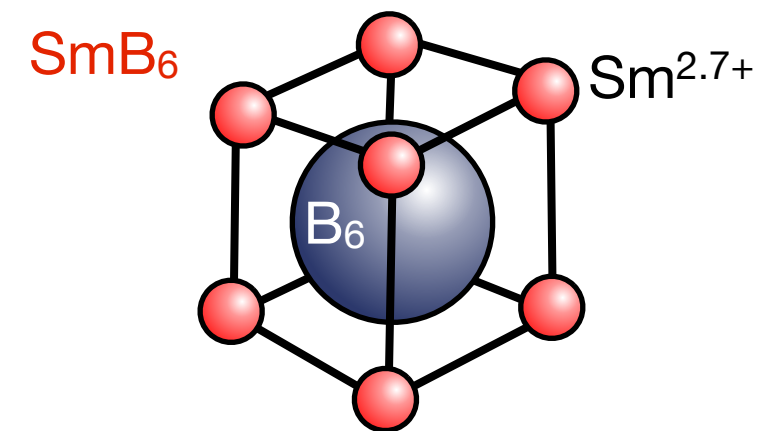
Kondo Insulators

Mott Phil Mag, 30,403,1974

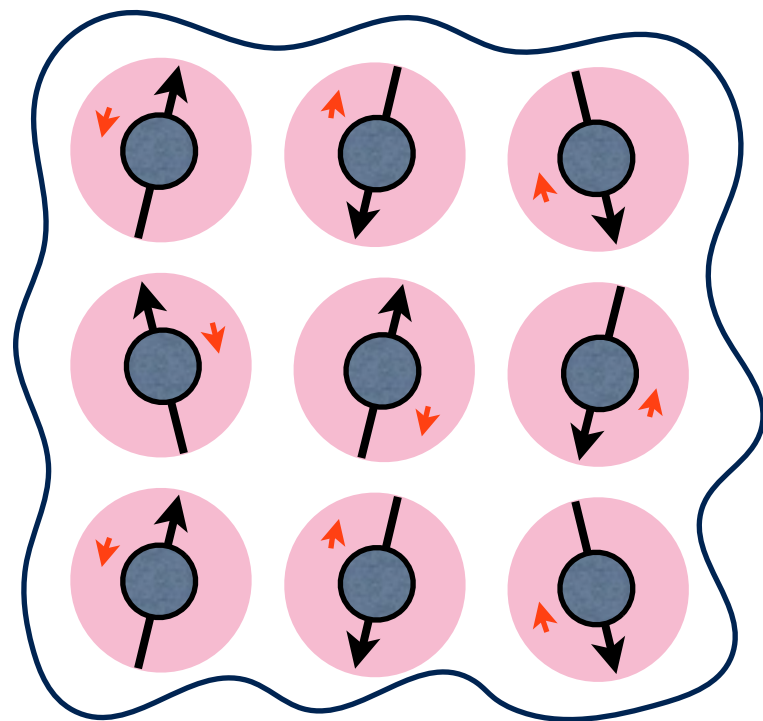
pressure are discussed. It is suggested that the low-pressure form of SmS is an excitonic insulator. In SmB₆ and high-pressure SmS a very small gap separates occupied from unoccupied states, this in our view being due to hybridization of 4f and 5d bands. The electrical properties are discussed ; if kT is greater than the gap



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MAGNETIC AND SEMICONDUCTING PROPERTIES OF SmB₆[†]

A. Menth and E. Buehler

Bell Telephone Laboratories, Murray Hill, New Jersey

and

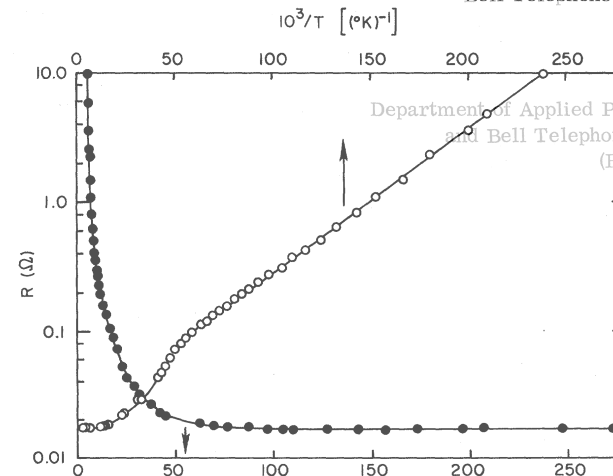
T. H. Geballe

Department of Applied Physics, Stanford University, Stanford, California,

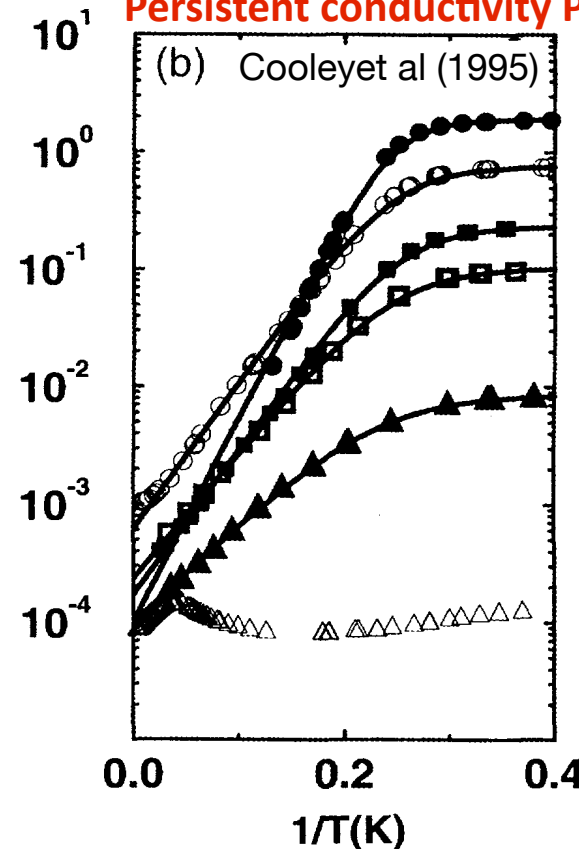
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(Received 21 November 1968)

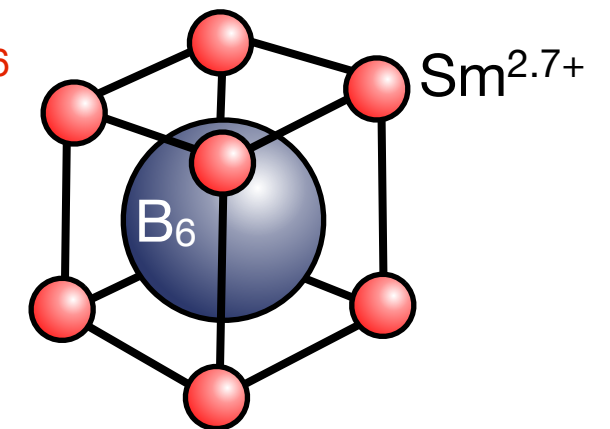
1968



Persistent conductivity Plateau

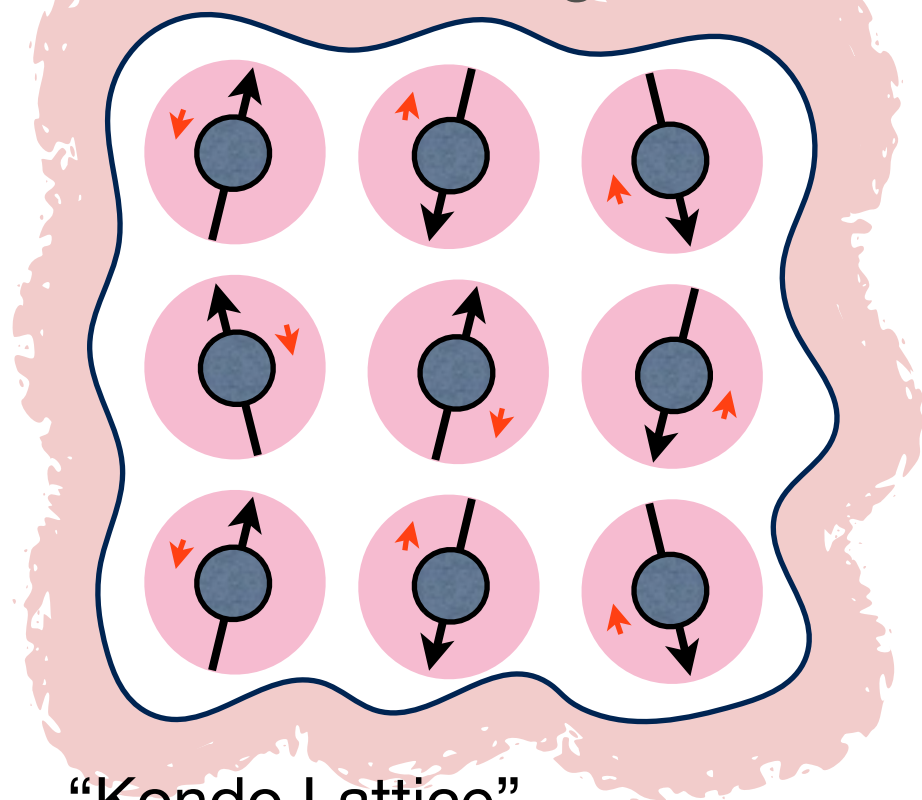


SmB₆



Kondo Insulators

Broken Kondo Singlets



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Topological Kondo Insulators

(Dzero, Sun, PC, Galitski (2010)

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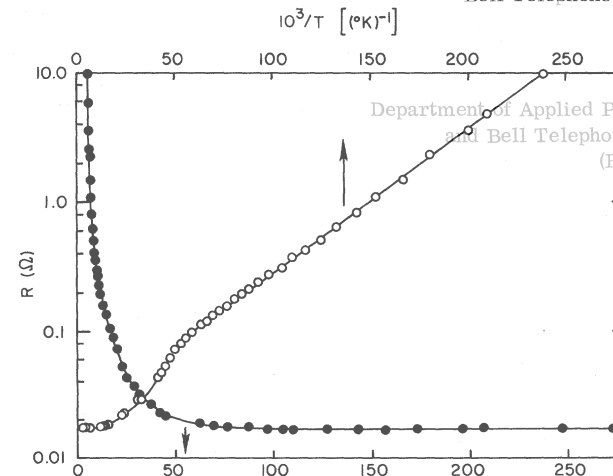
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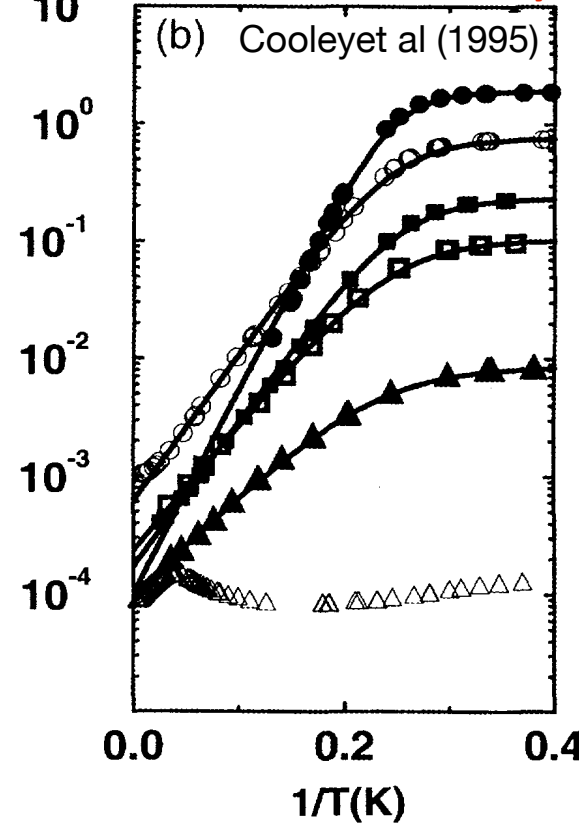
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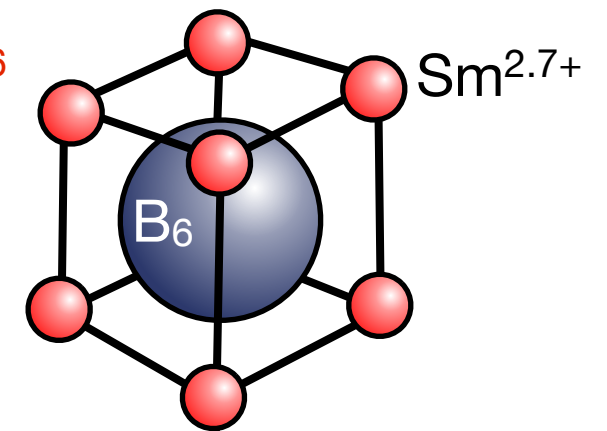
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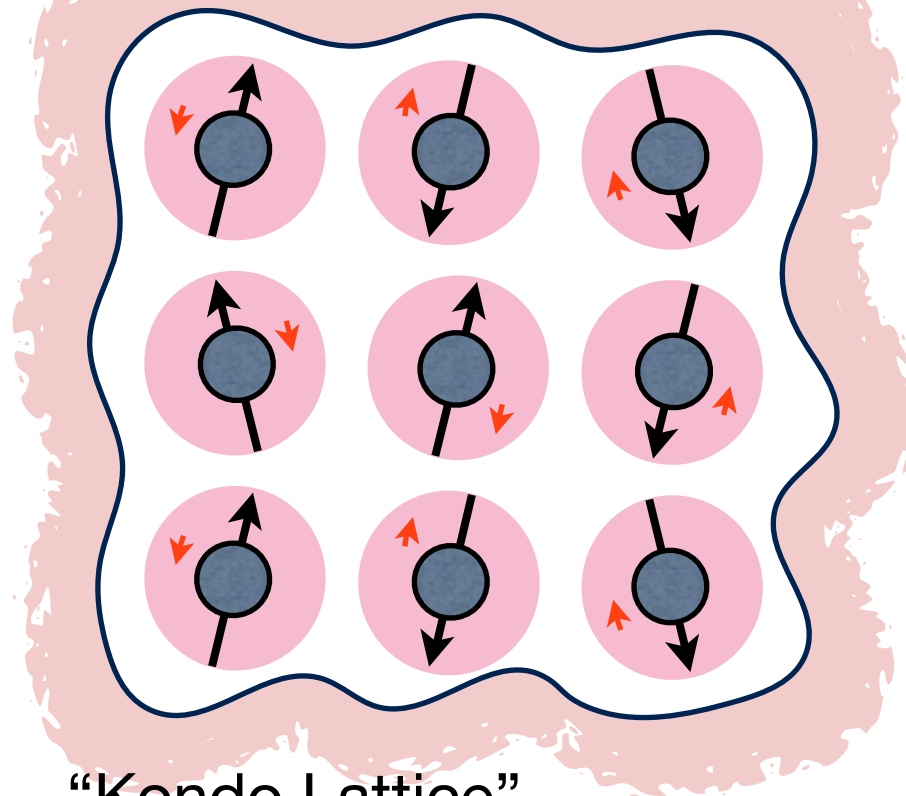


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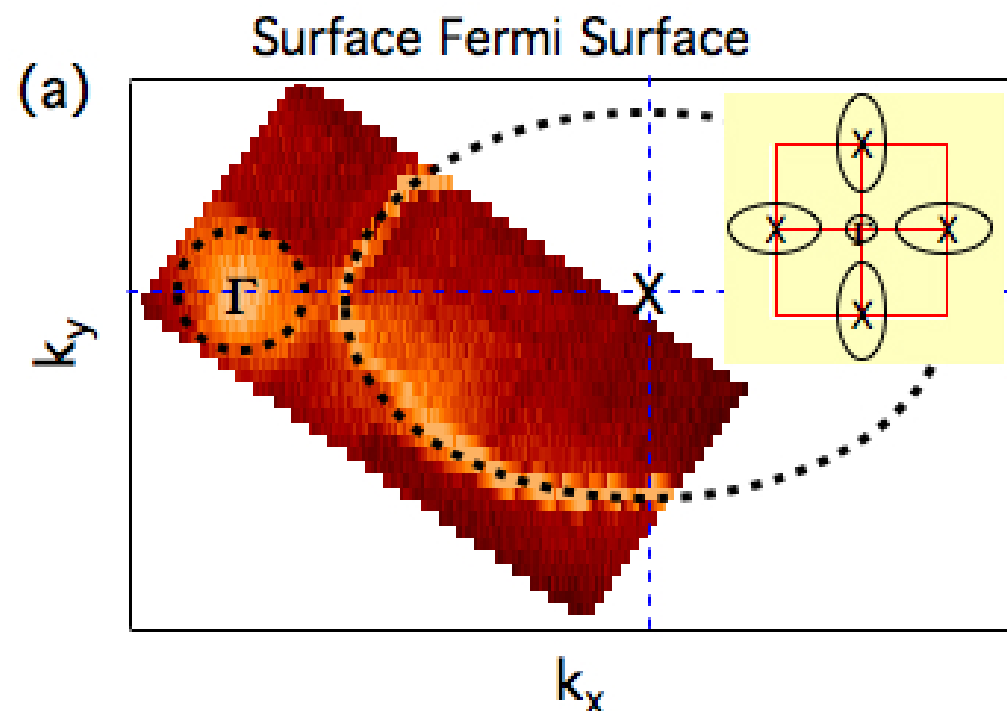


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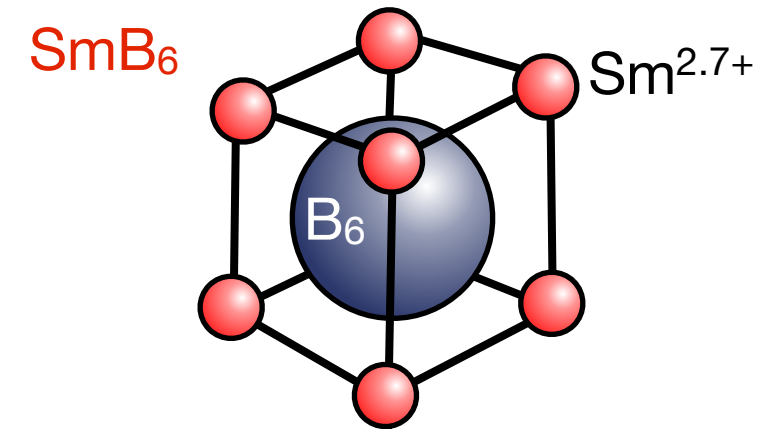
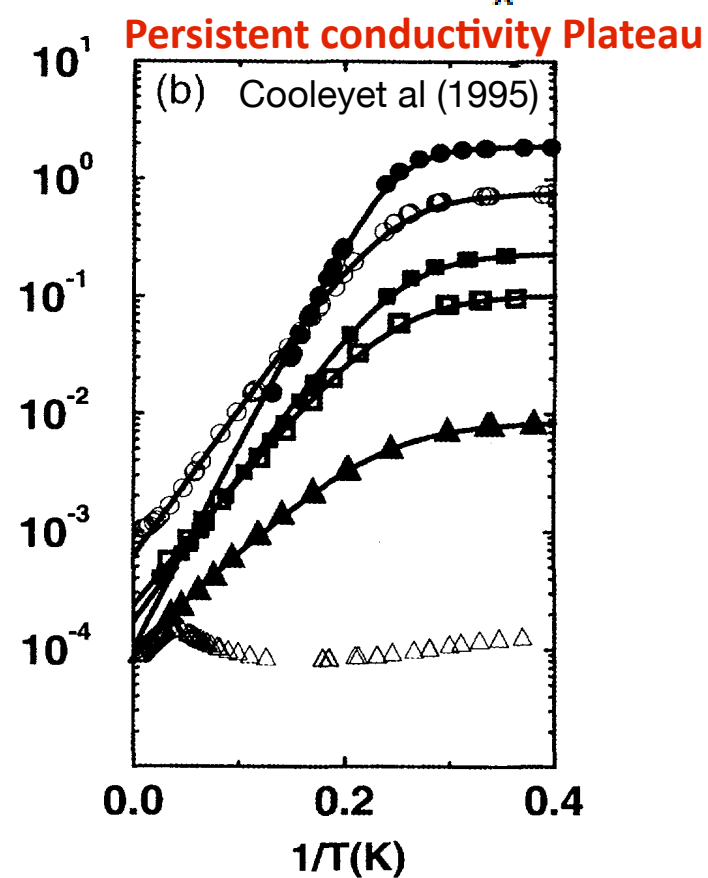
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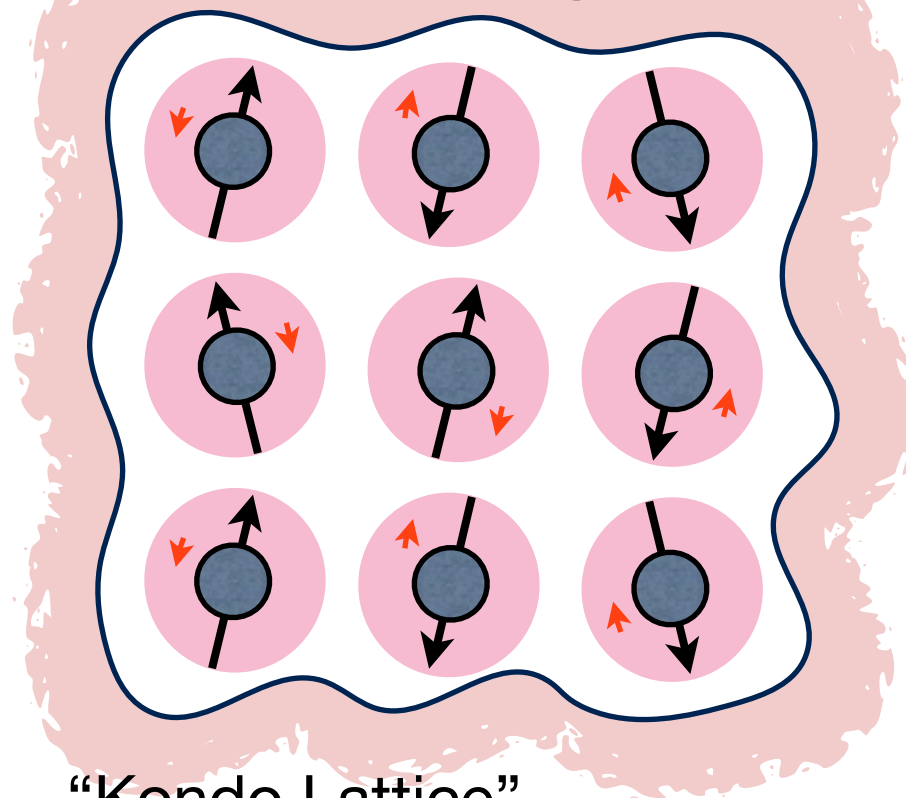
(b) B_6
Energy (eV)

Neupane, arXiv: 1306.463
Nature(2013).



Kondo Insulators

Broken Kondo Singlets

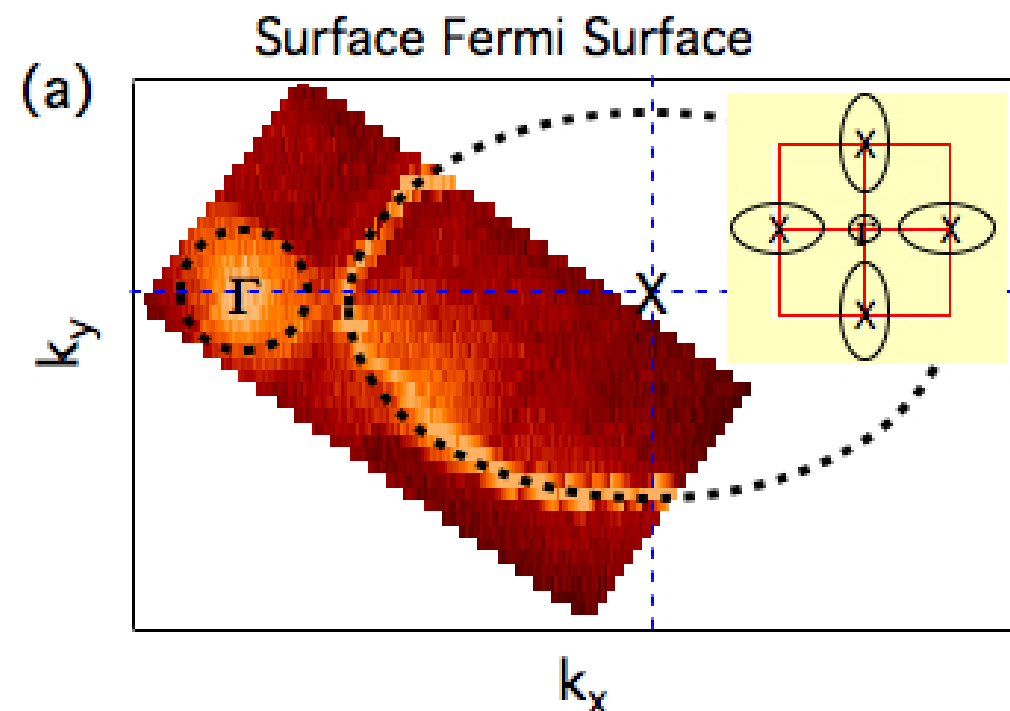


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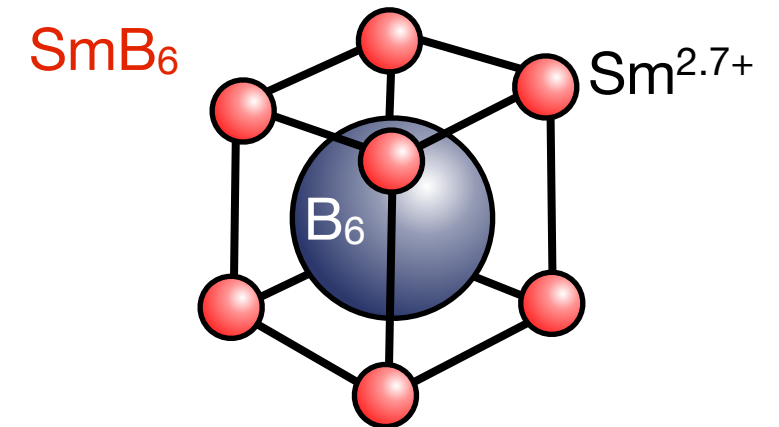
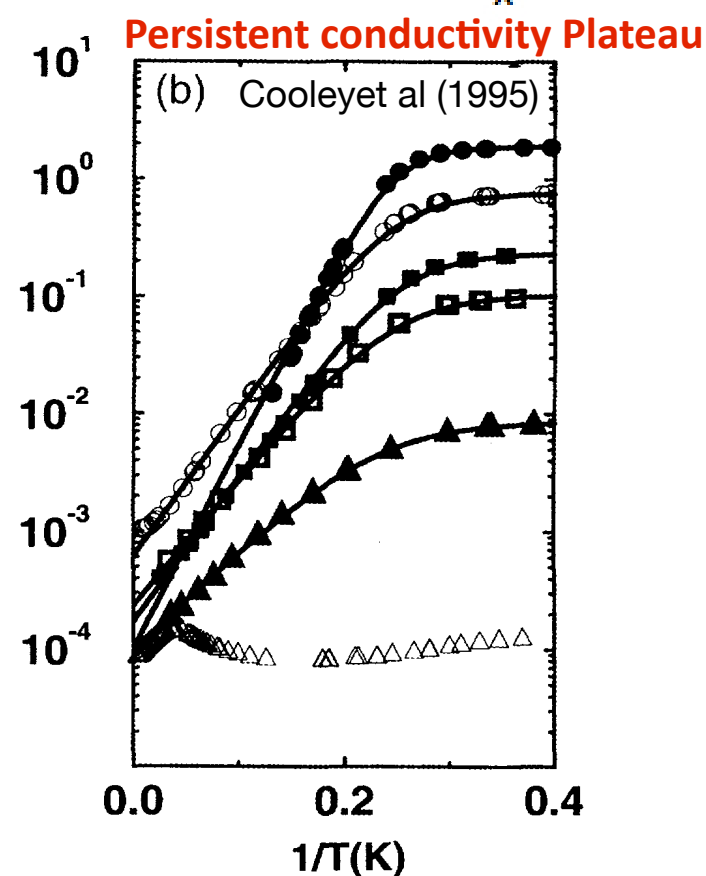
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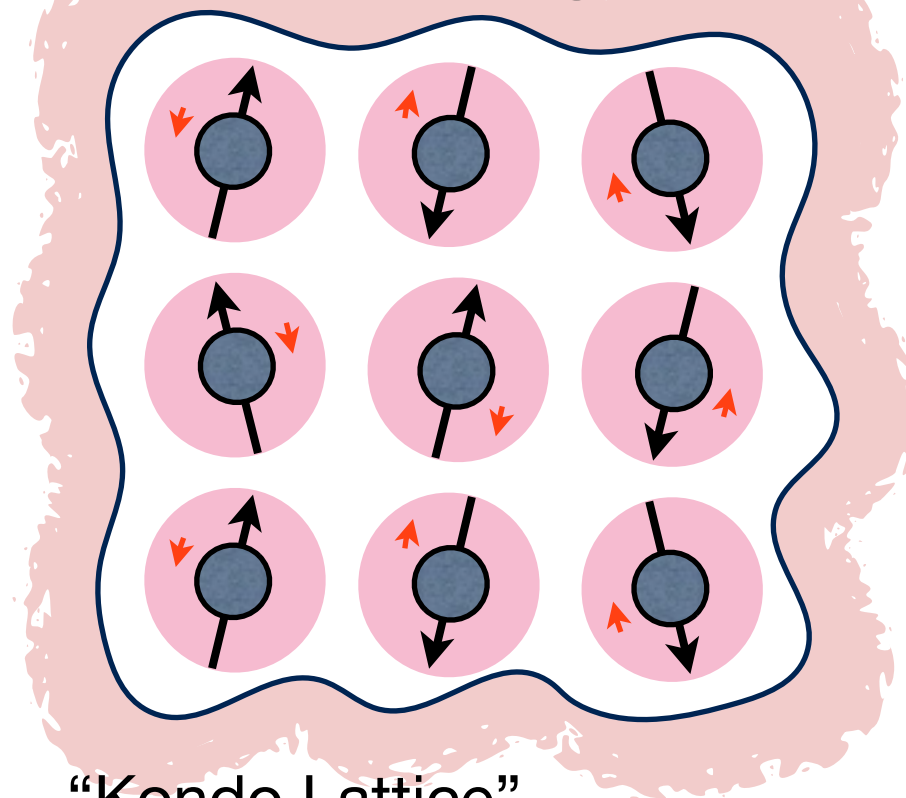
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Collin Broholm: what happens to the correlations between d- and f-electrons as topological Kondo insulator develops?

Kondo Insulators

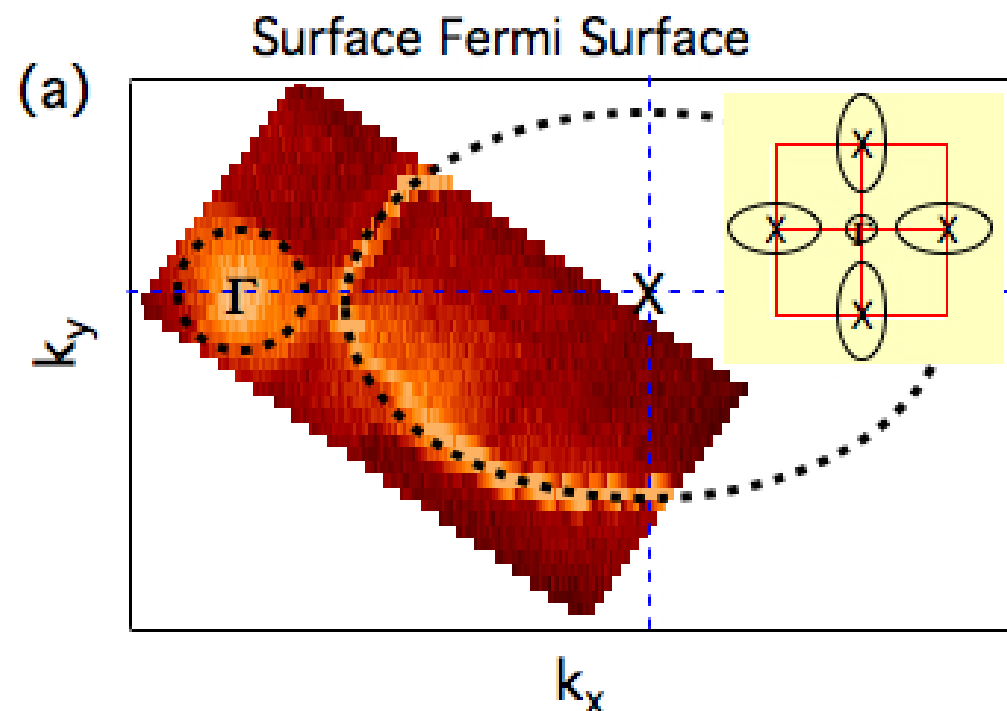
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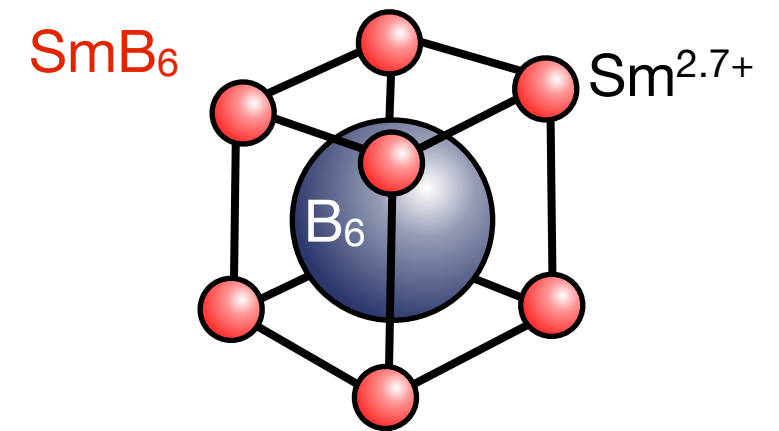
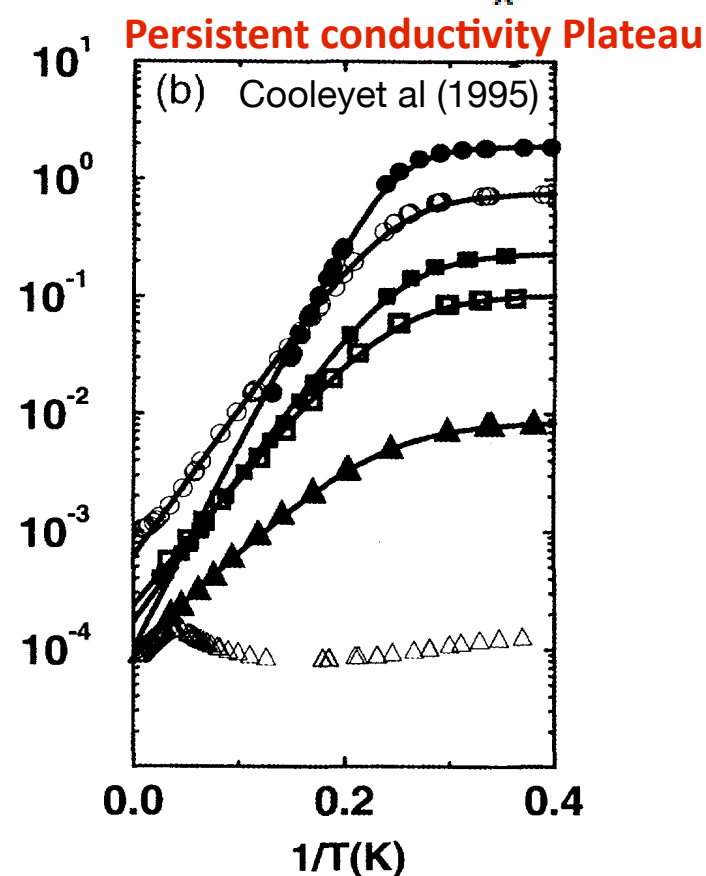
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(b) B_6^{2+}
Energy (eV)

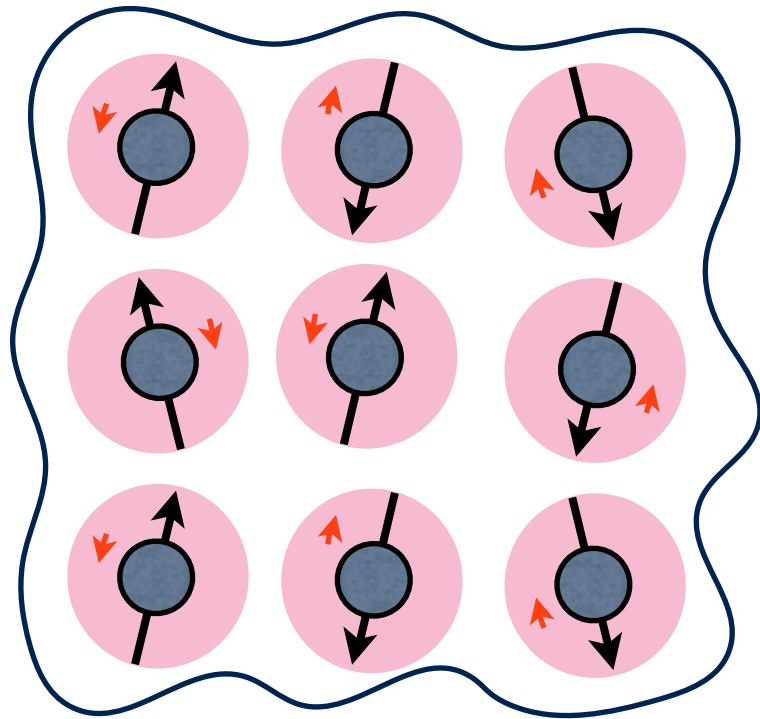
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Collin Broholm: what happens to the correlations between d- and f-electrons as topological Kondo insulator develops?

Collin Broholm: what collective excitations result from the excitonic Kondo lattice

Heavy Fermion Metals



“Kondo Lattice”

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Topological Kondo Insulators

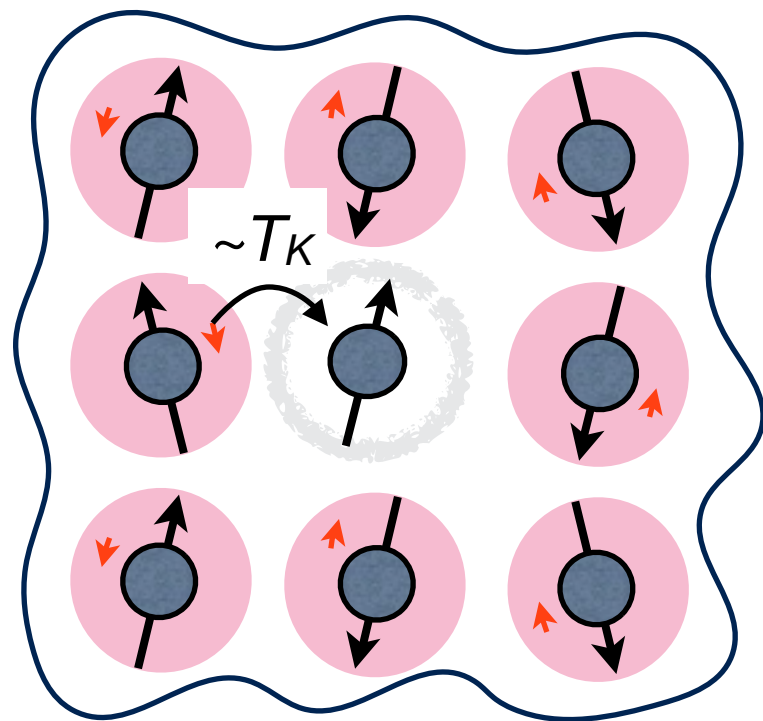
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Heavy Fermion Metals:

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Coherent HFs~Hole doped KIs



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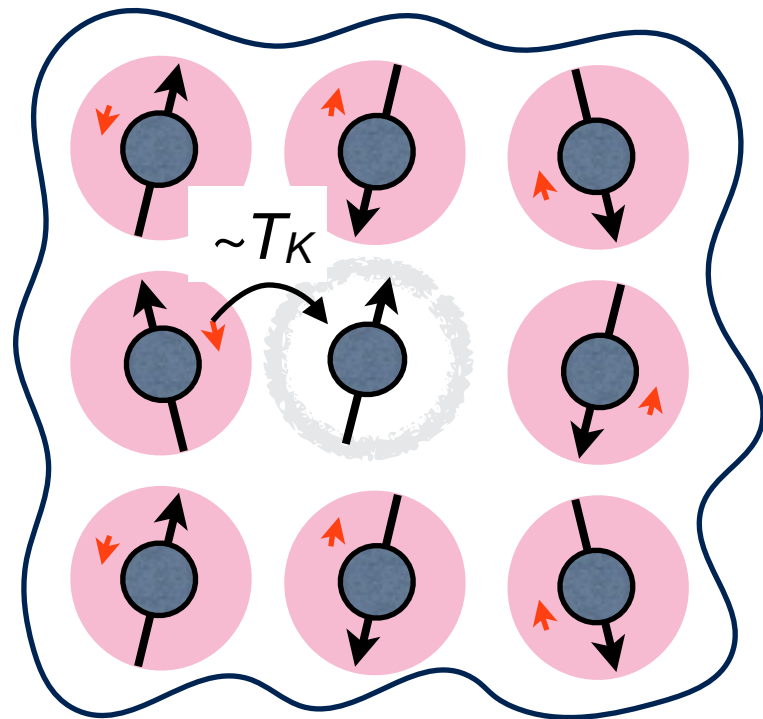
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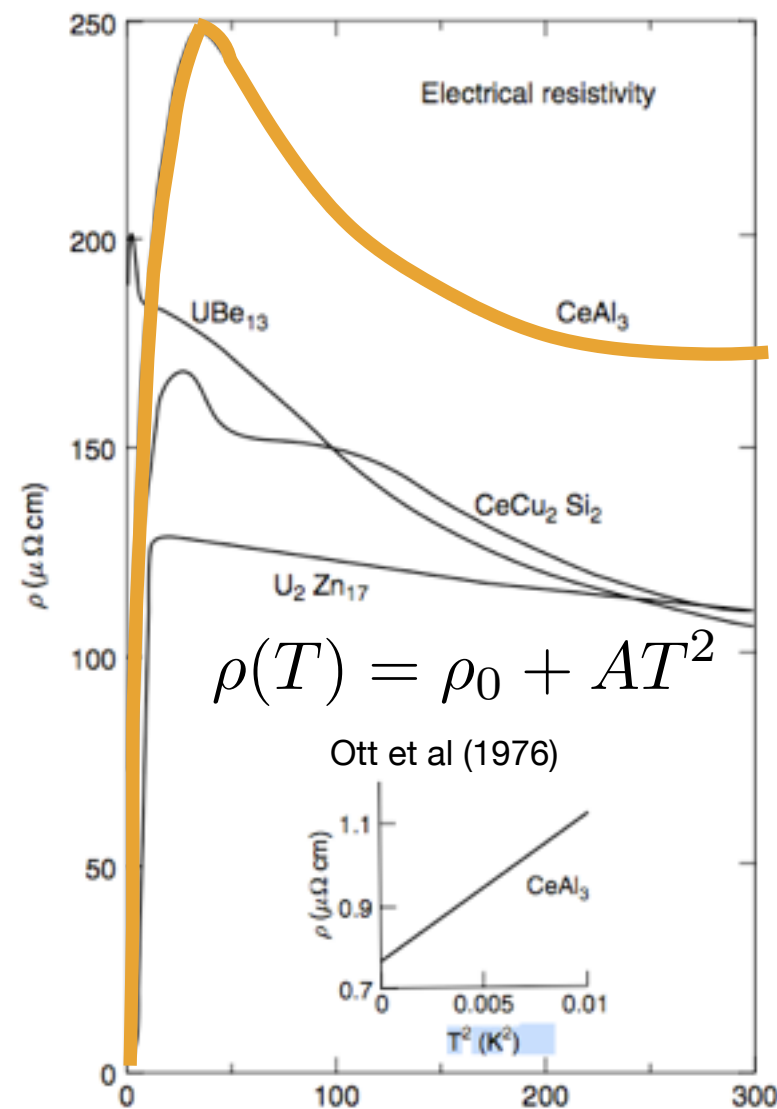
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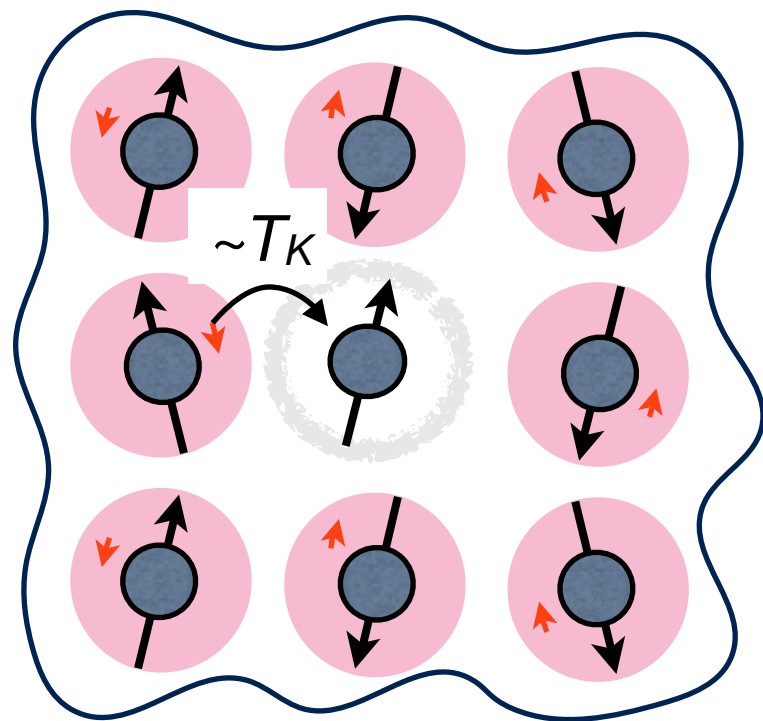
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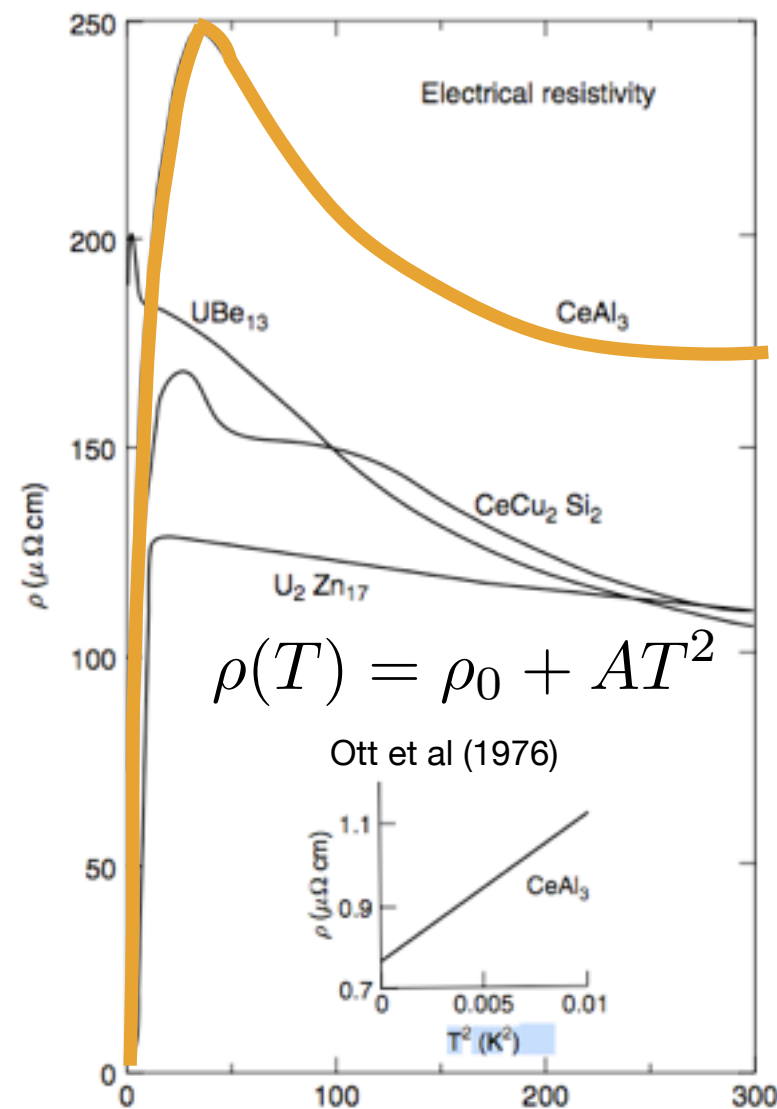
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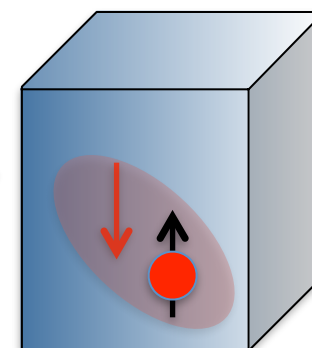
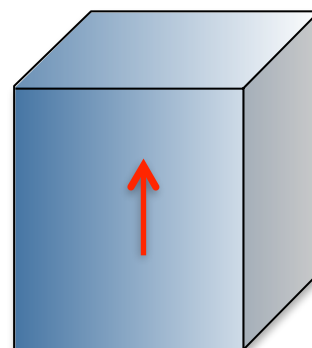
Heavy Fermion Metals:



$$\frac{J}{N} c_{j\alpha} S_{\alpha\beta} \equiv \bar{V}_j f_{j\beta}$$

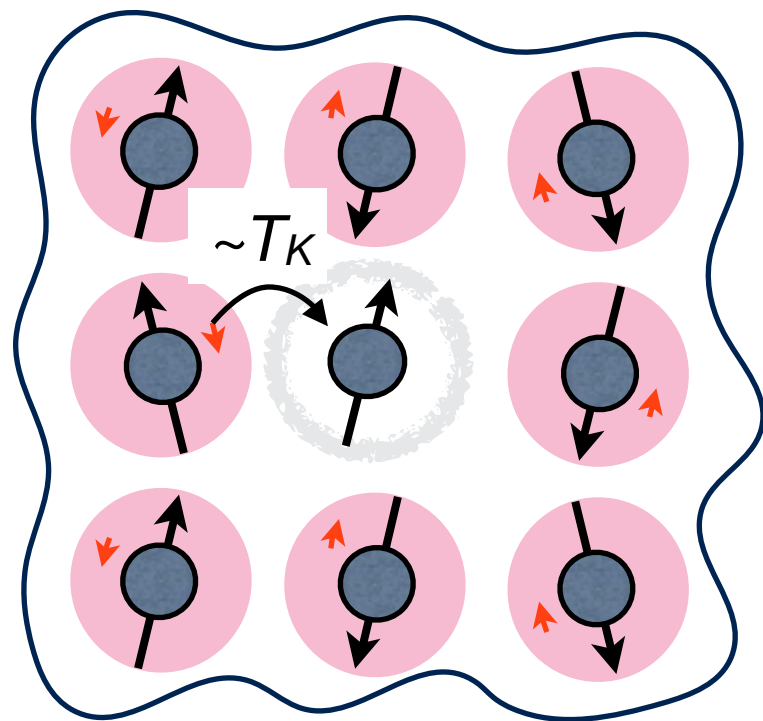
Composite
Fermion

Singlet formation



Heavy Fermion Metals

Coherent HFs~Hole doped KIs



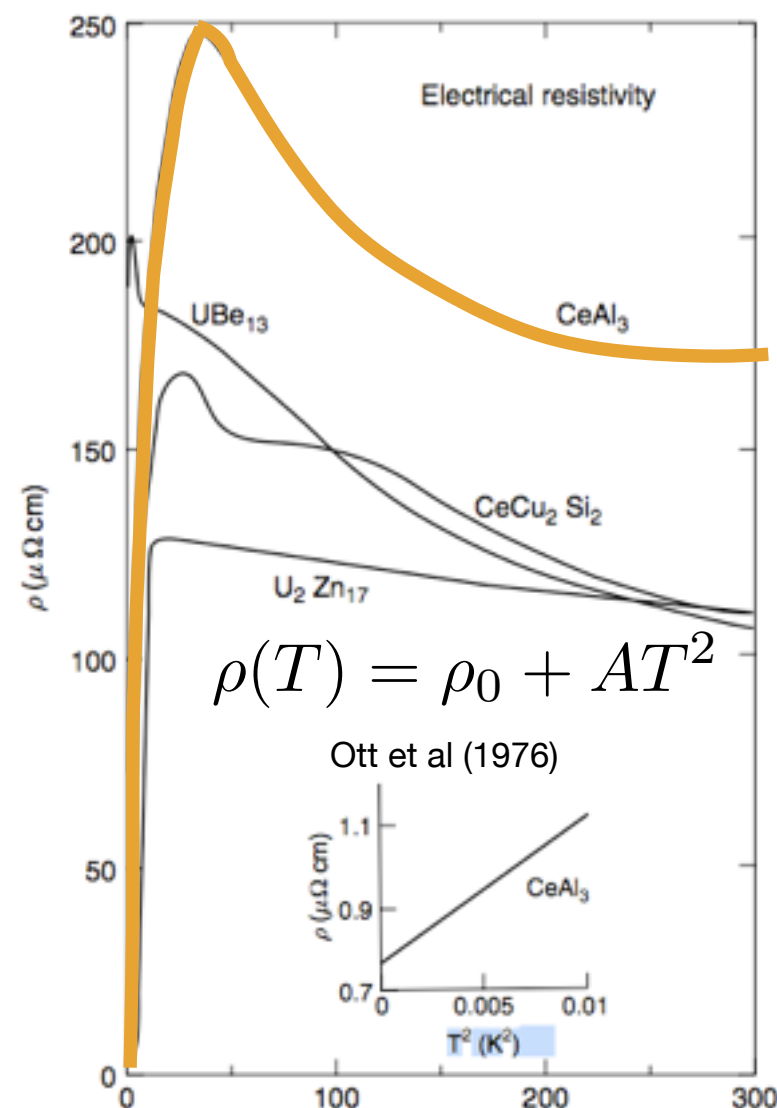
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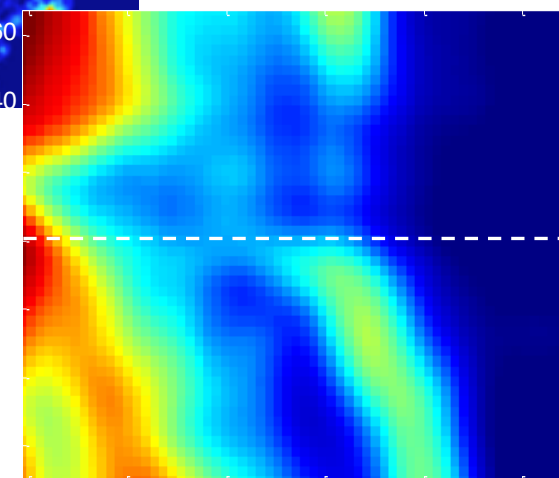
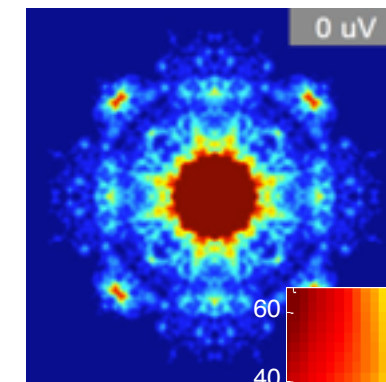
Topological Kondo Insulators

(Dzero, Sun, PC, Galitski (2010)
Wolgast et al (2013).

Heavy Fermion Metals:



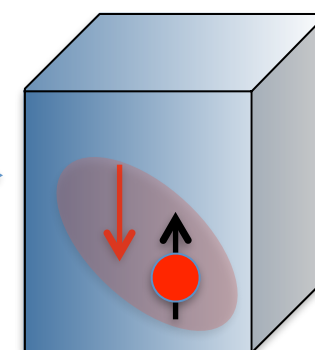
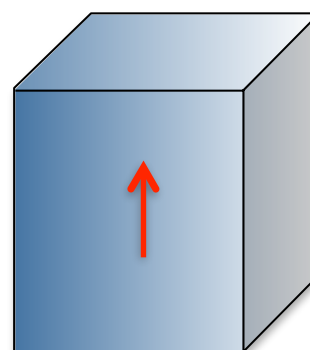
Ali Yazdani:
spectroscopically
image the composite HF?



$$\frac{J}{N} c_{j\alpha} S_{\alpha\beta} \equiv \bar{V}_j f_{j\beta}$$

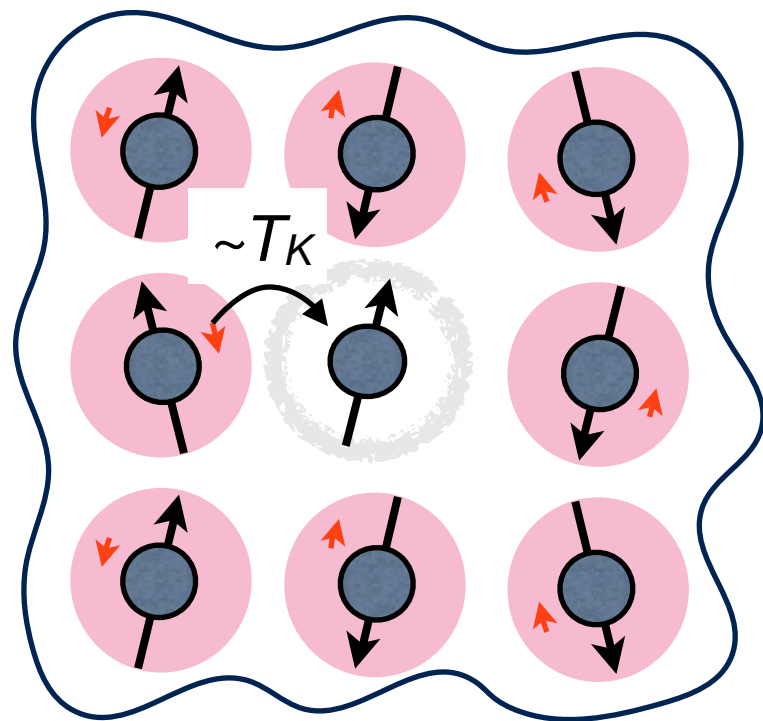
Composite
Fermion

Singlet formation



Heavy Fermion Metals

Coherent HFs~Hole doped KIs



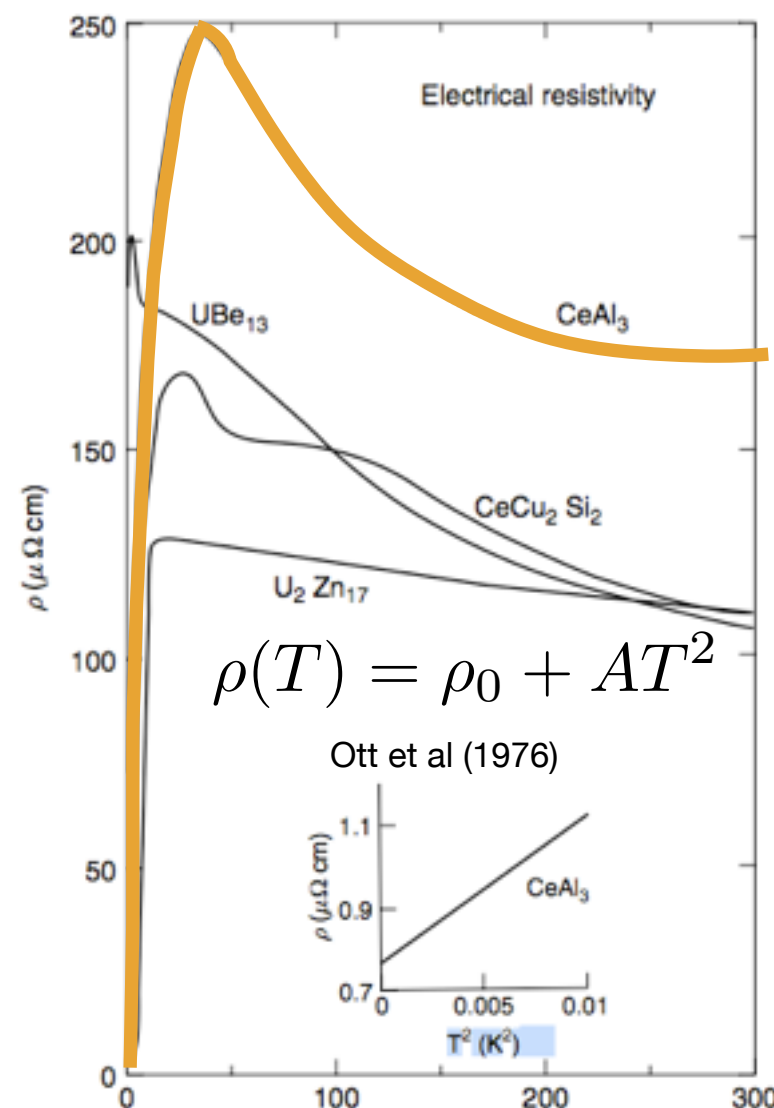
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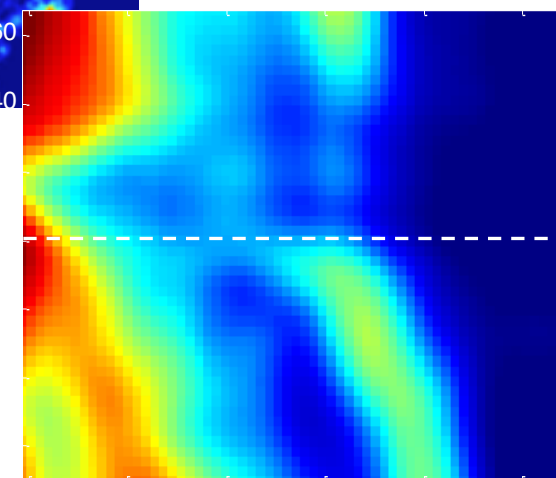
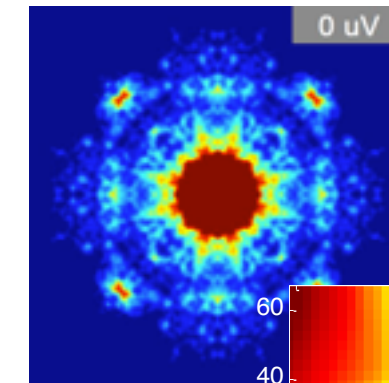
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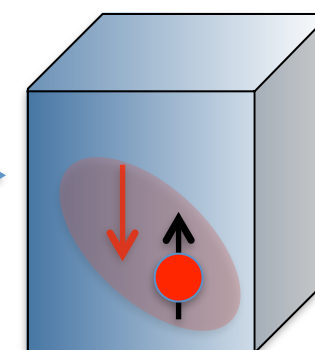
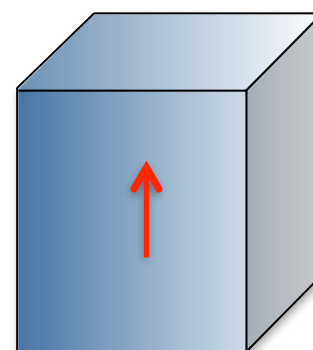
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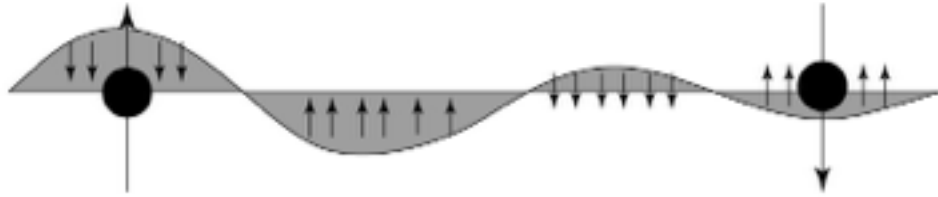
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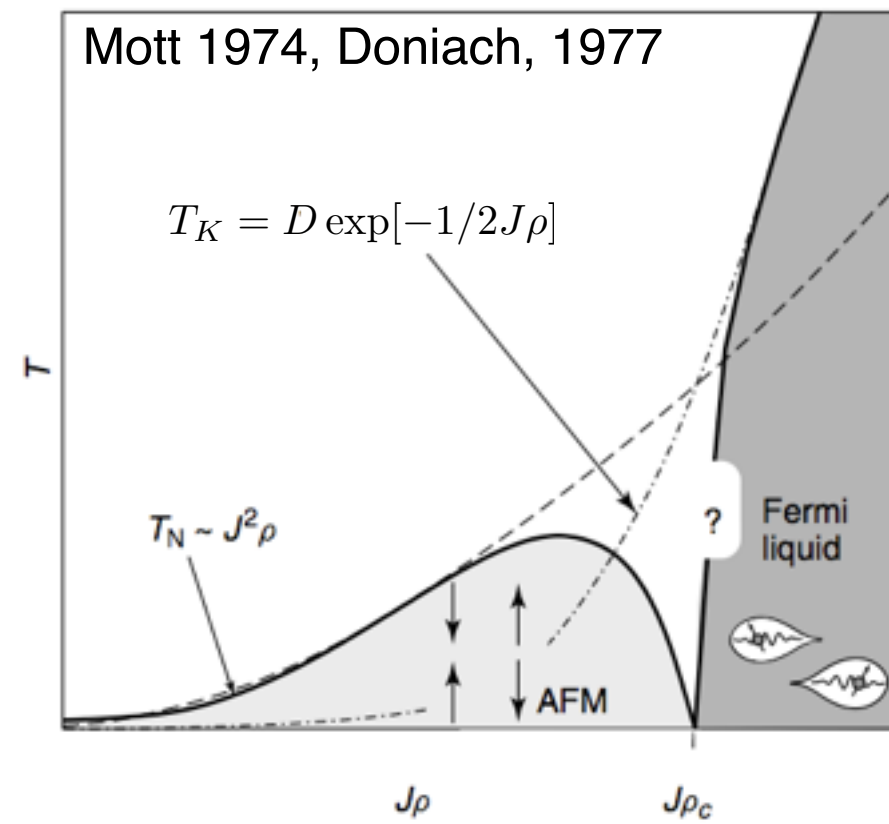


Quantum Criticality & SC

RKKY Interaction



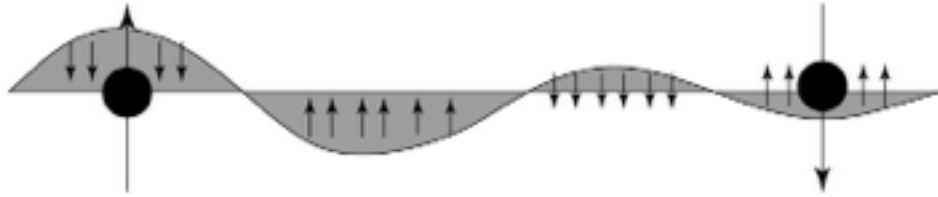
Mott 1974, Doniach, 1977



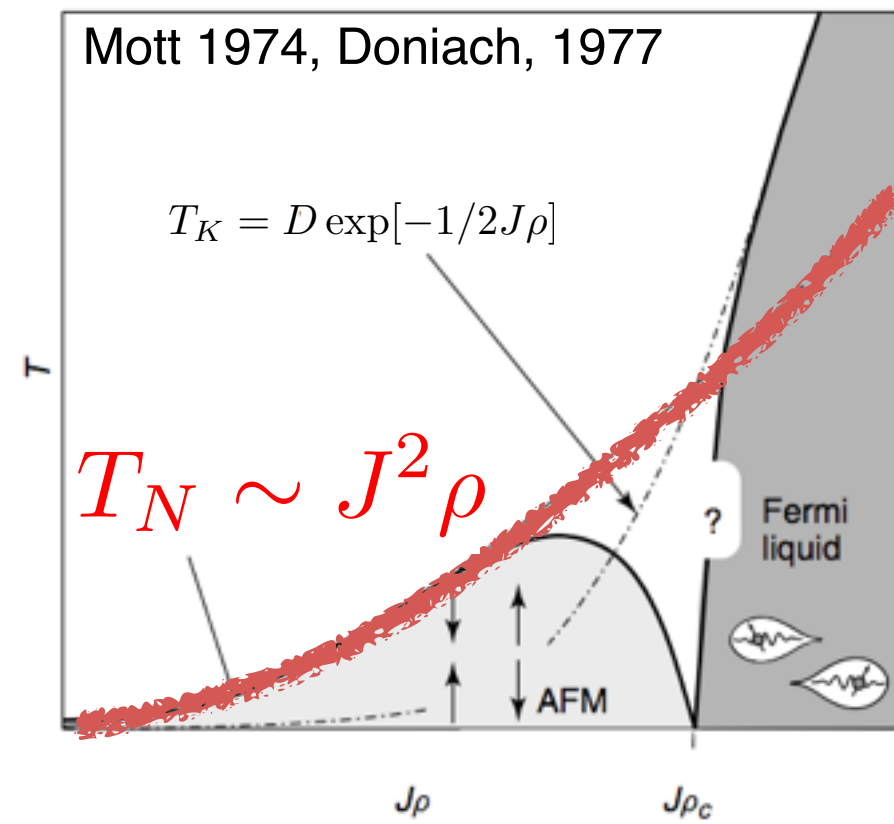
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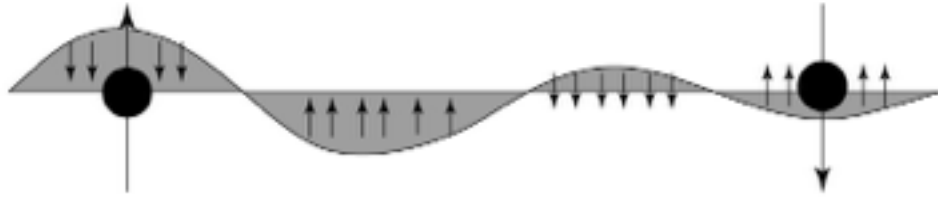
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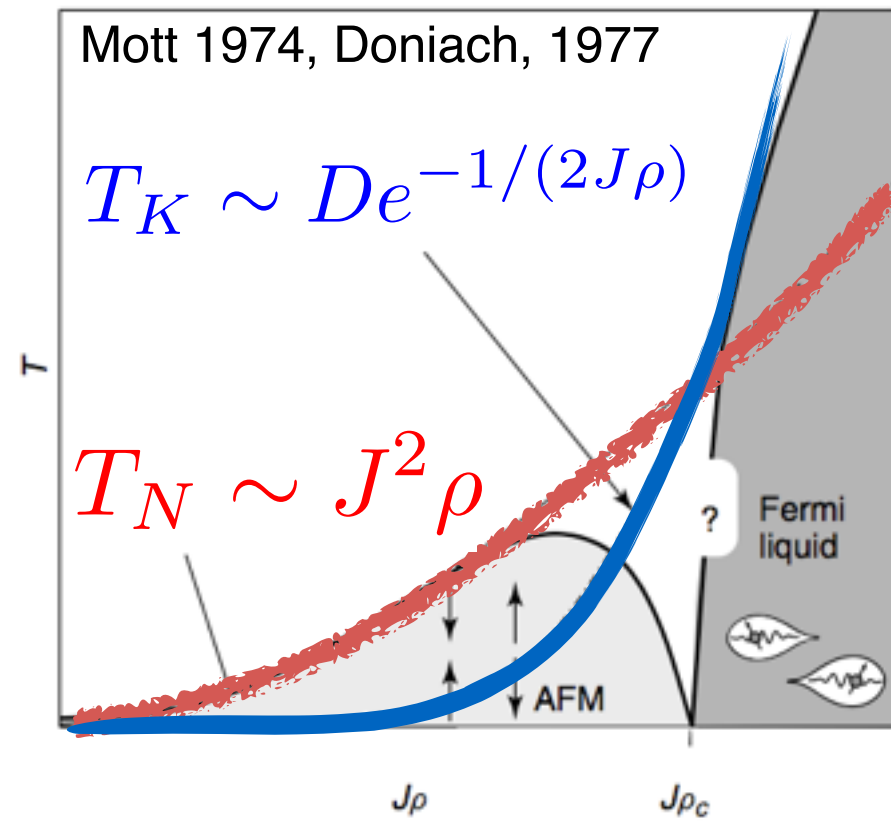
RKKY Interaction



Mott 1974, Doniach, 1977

$$T_K \sim D e^{-1/(2J\rho)}$$

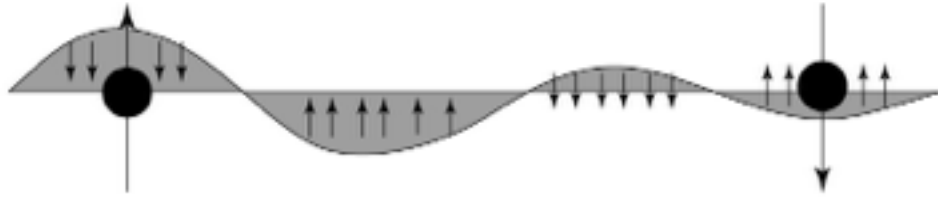
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>

Quantum Criticality & SC

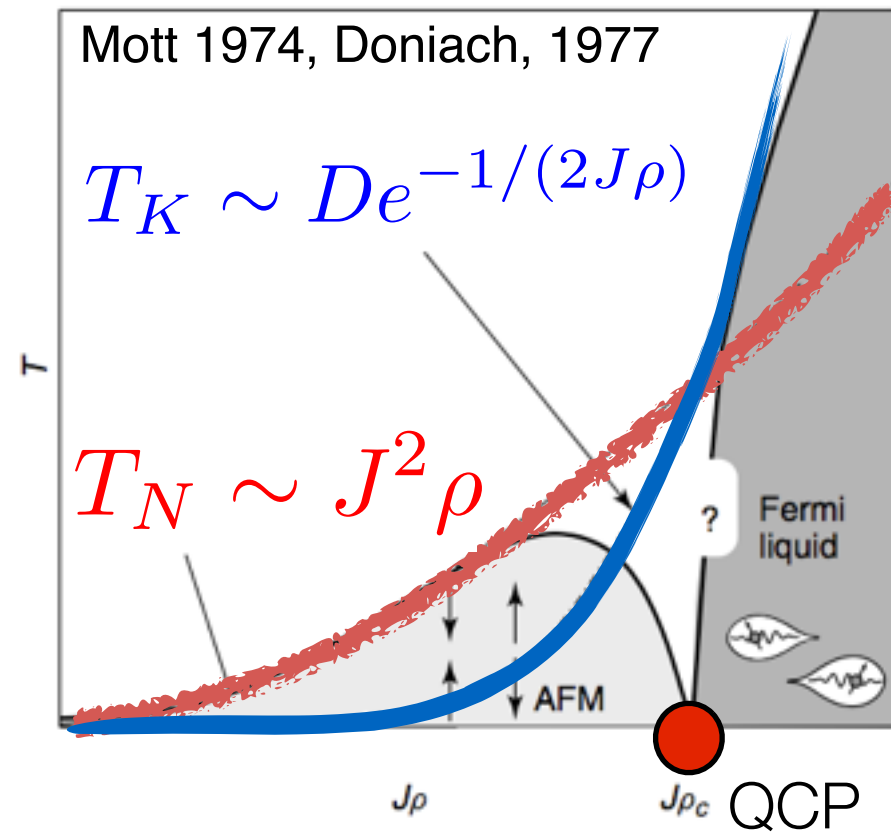
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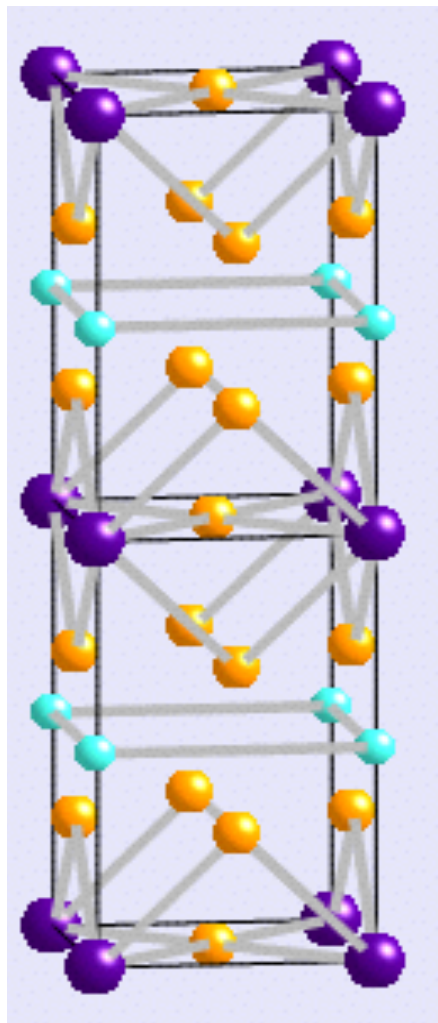
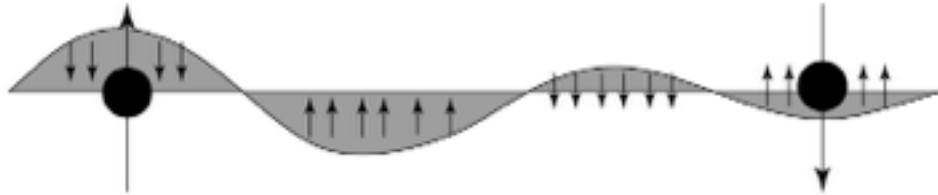
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Quantum Criticality & SC

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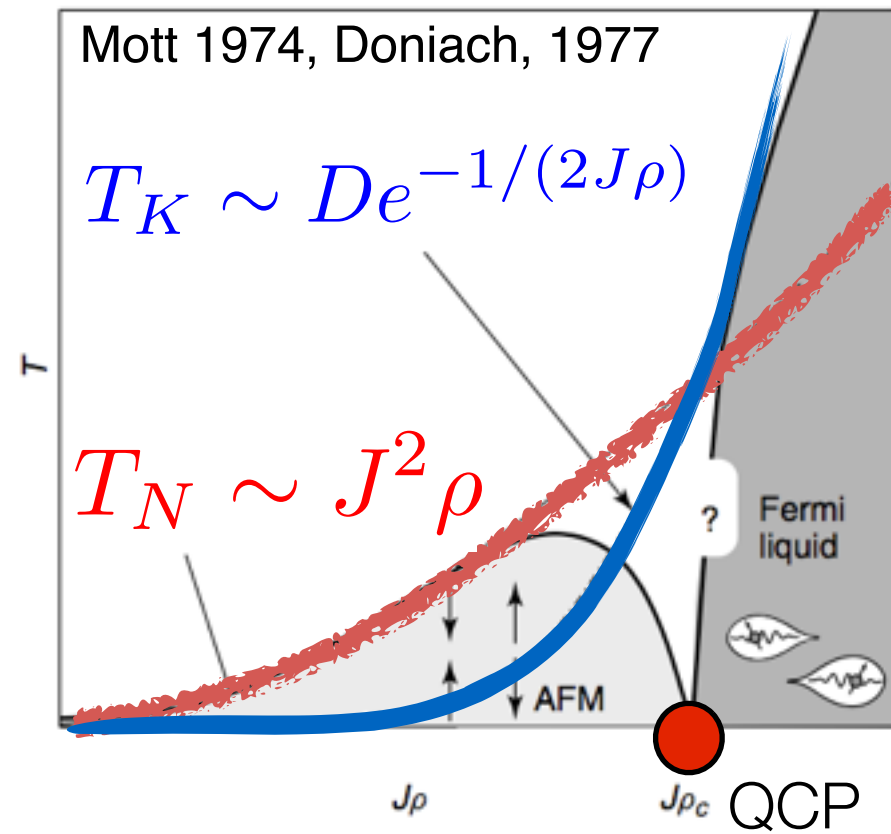


1-1-5
Materials

Mott 1974, Doniach, 1977

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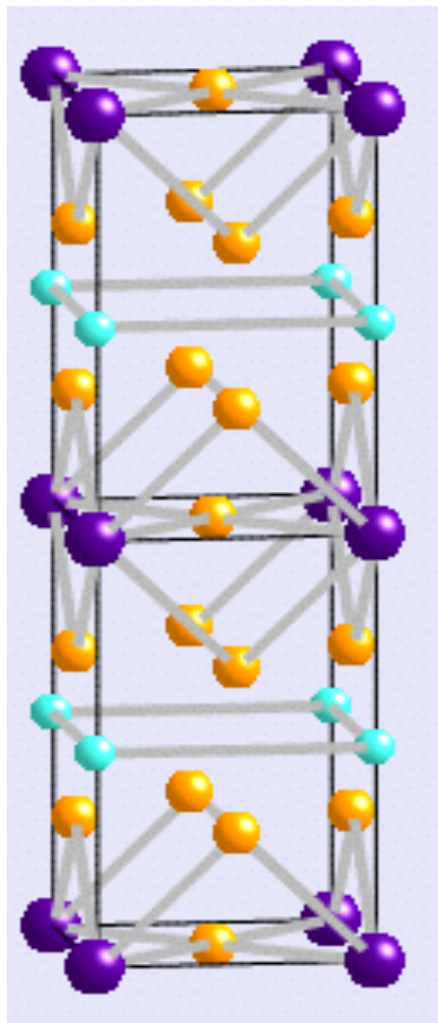
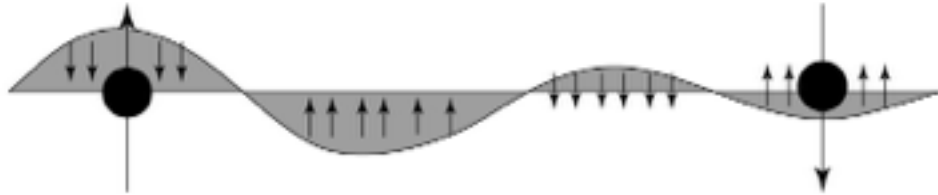
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Quantum Criticality & SC

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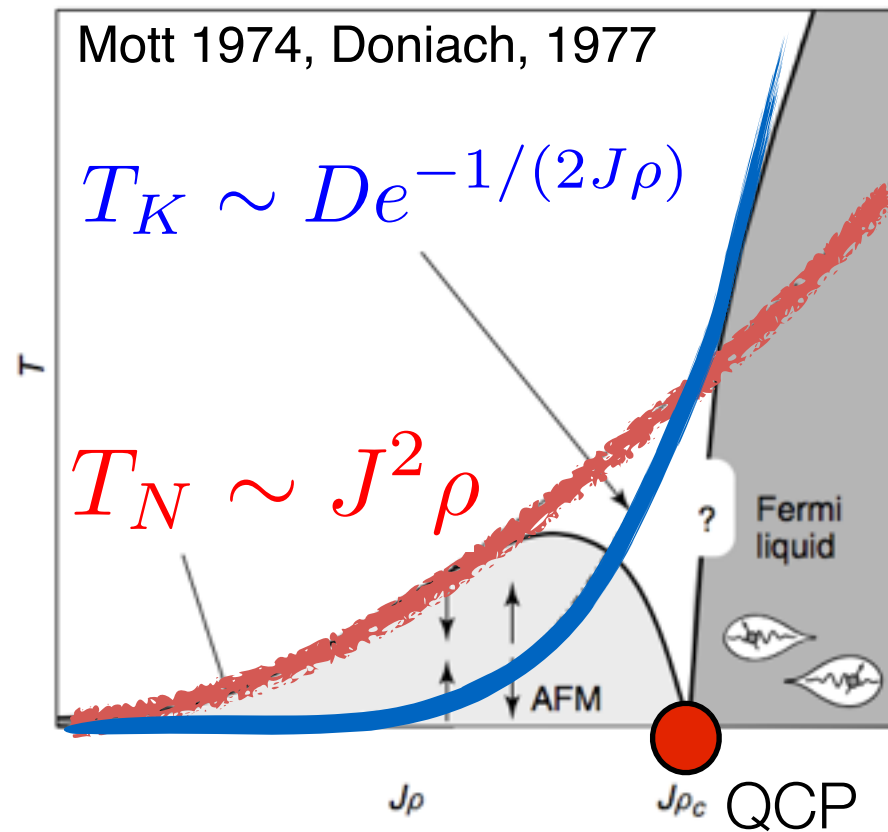
**1-1-5
Materials**

Joe Thompson

Mott 1974, Doniach, 1977

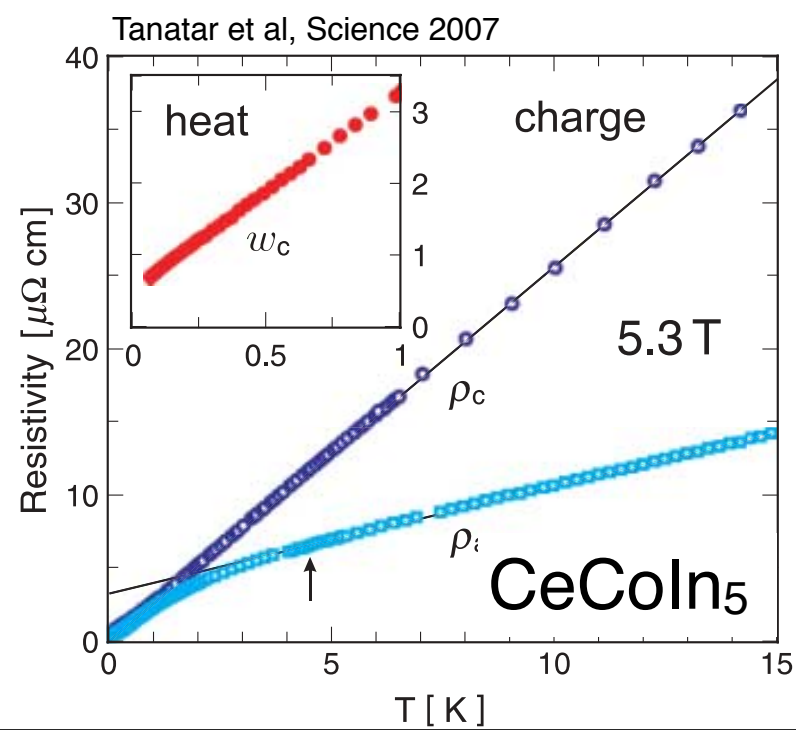
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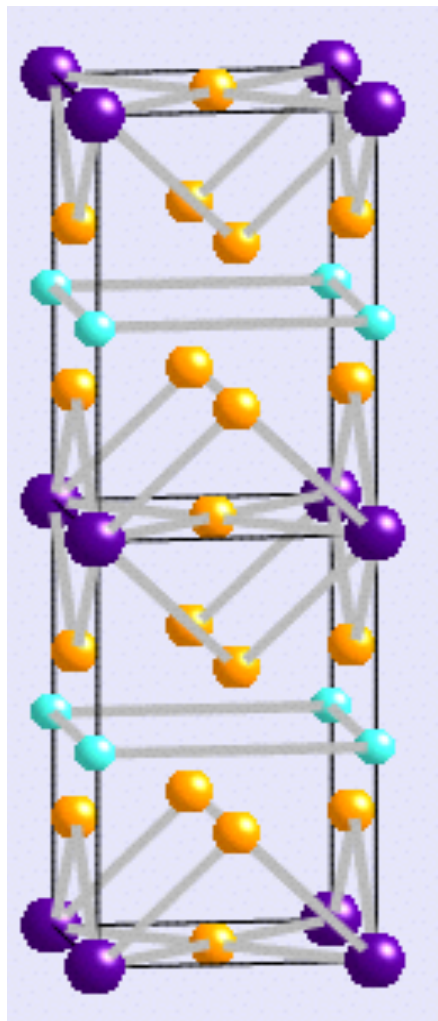
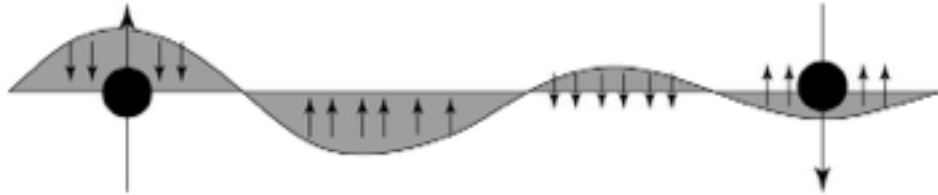
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**Thompson: Linear
Resistance due to magnetic
quantum Criticality?**



Quantum Criticality & SC

RKKY Interaction



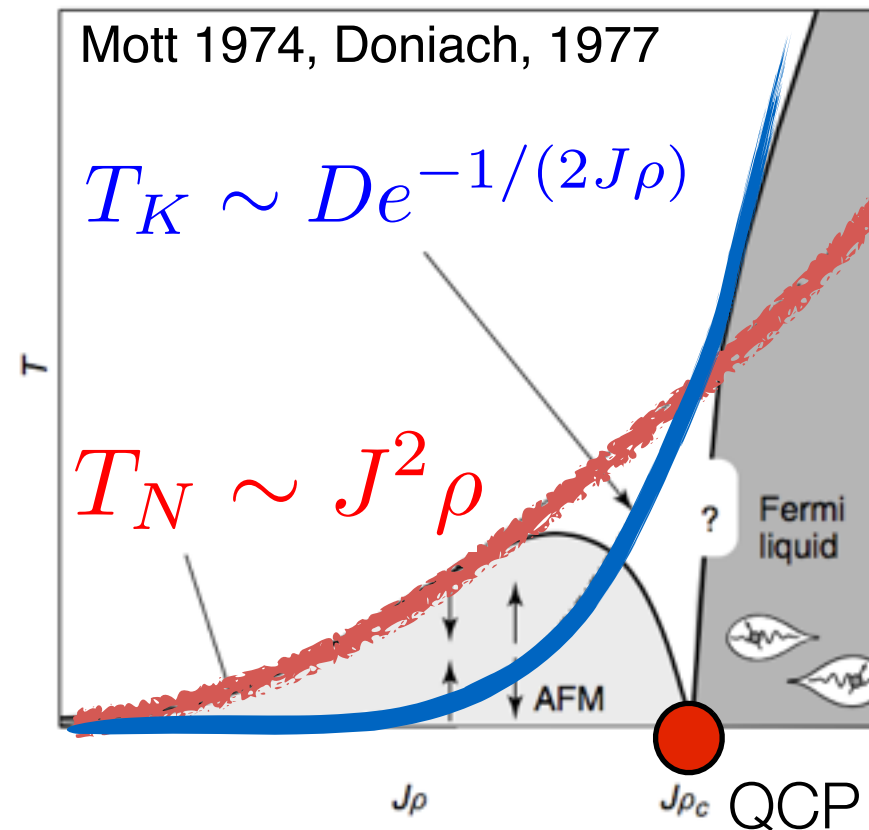
1-1-5
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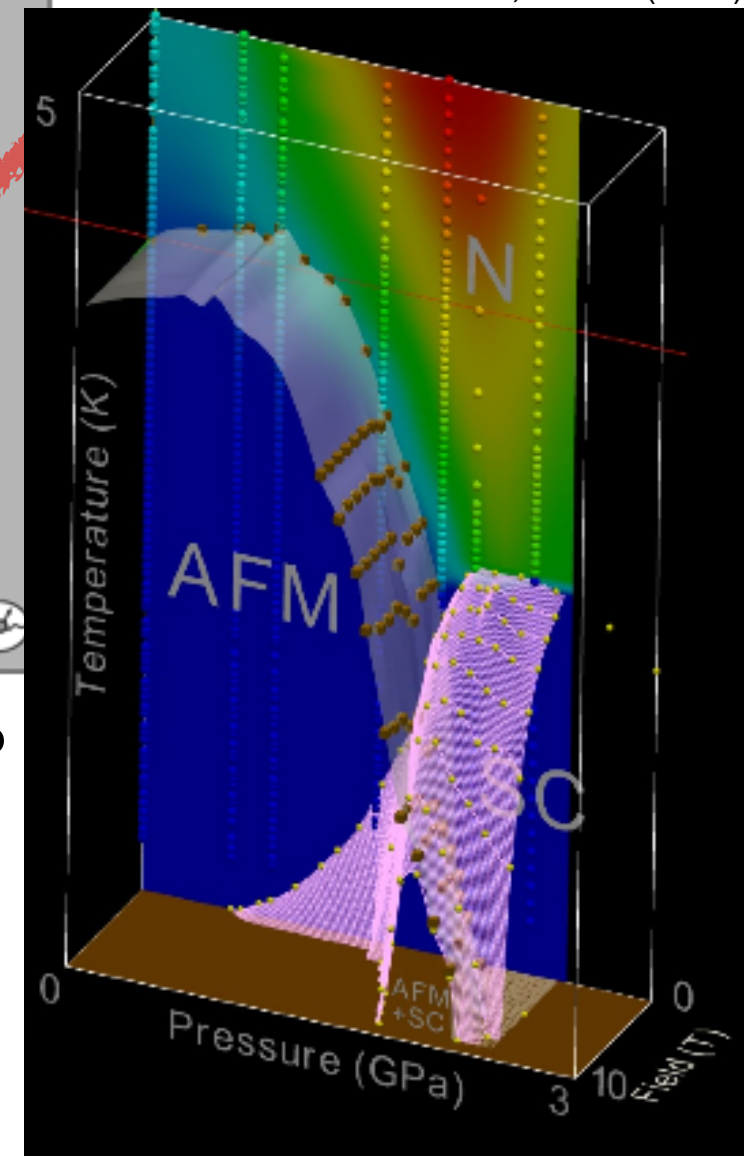
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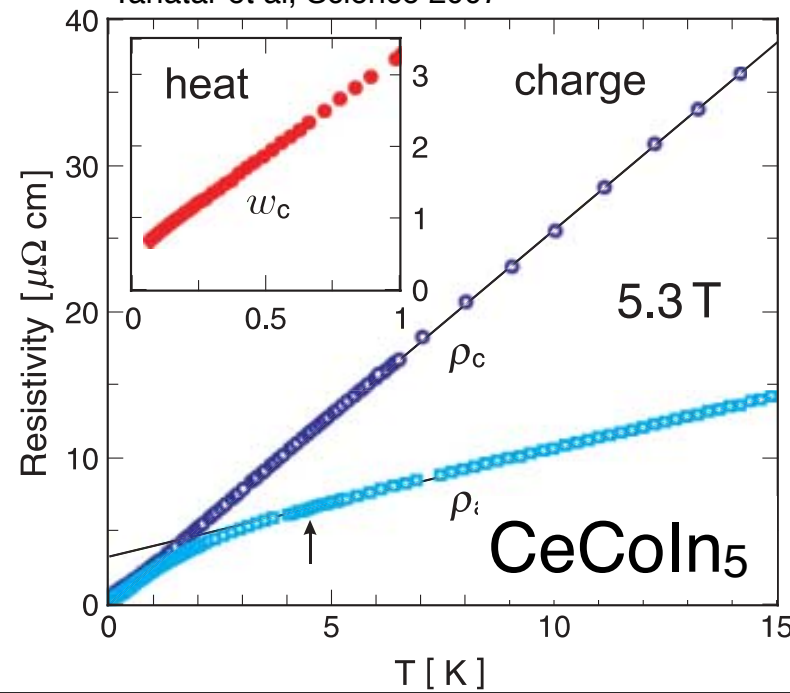


Tusan Park et al, Nature (2005)



**Thompson: Linear
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Tanatar et al, Science 2007

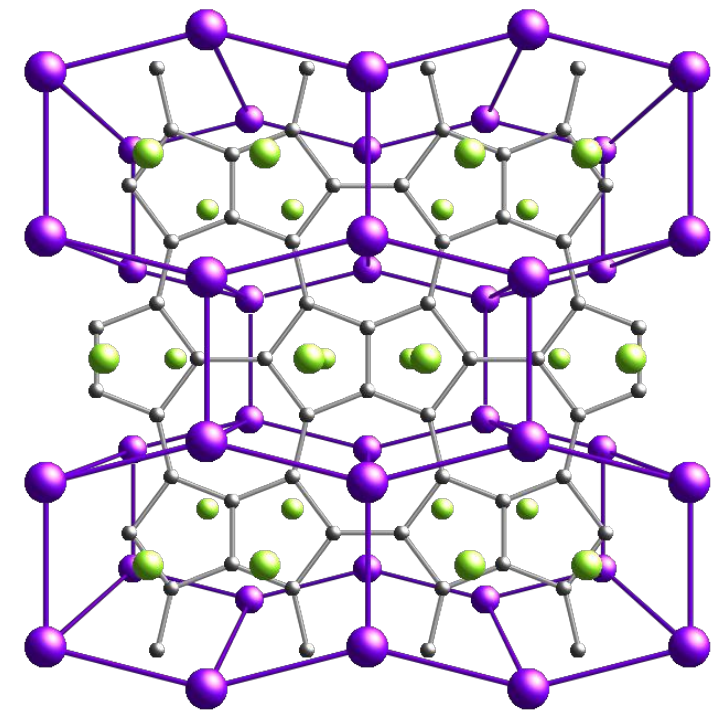


**Thompson: How does a lo
moment time-share between
SC and AFM?**

$$b \rightleftharpoons f$$

Strange Metals.

Yosuke Matsumoto

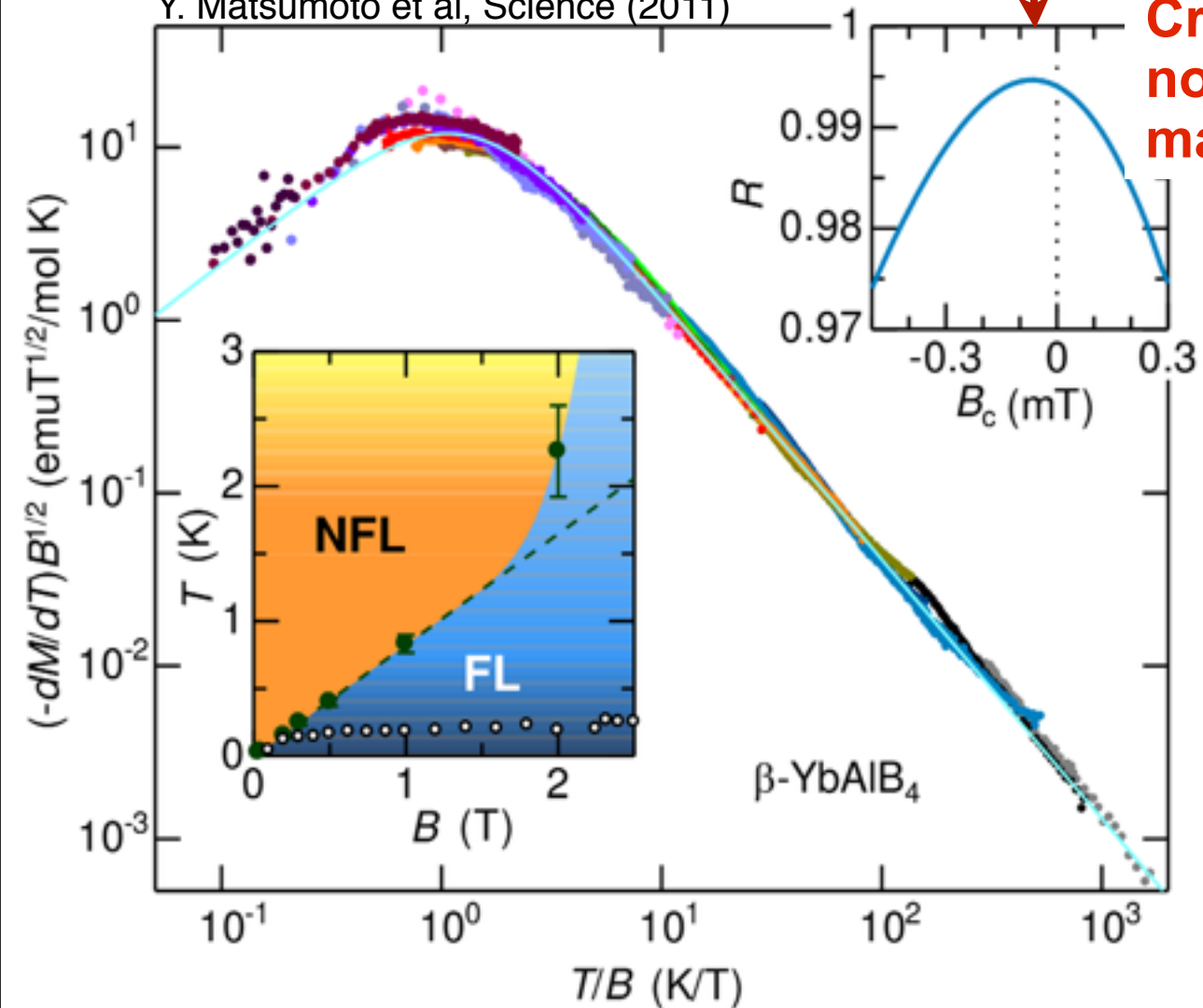


β -YbAlB₄

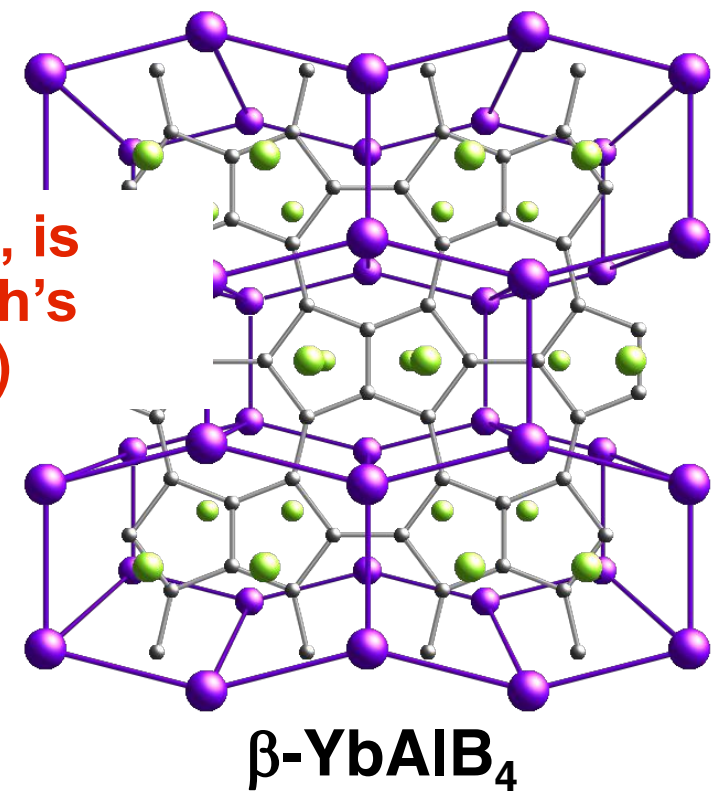
Strange Metals.

Yosuke Matsumoto

Y. Matsumoto et al, Science (2011)

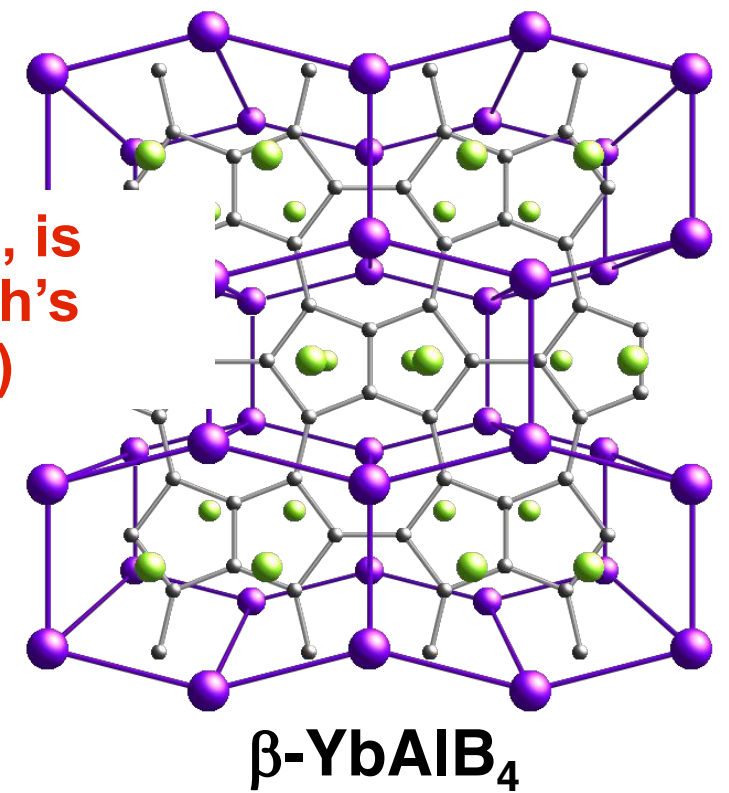
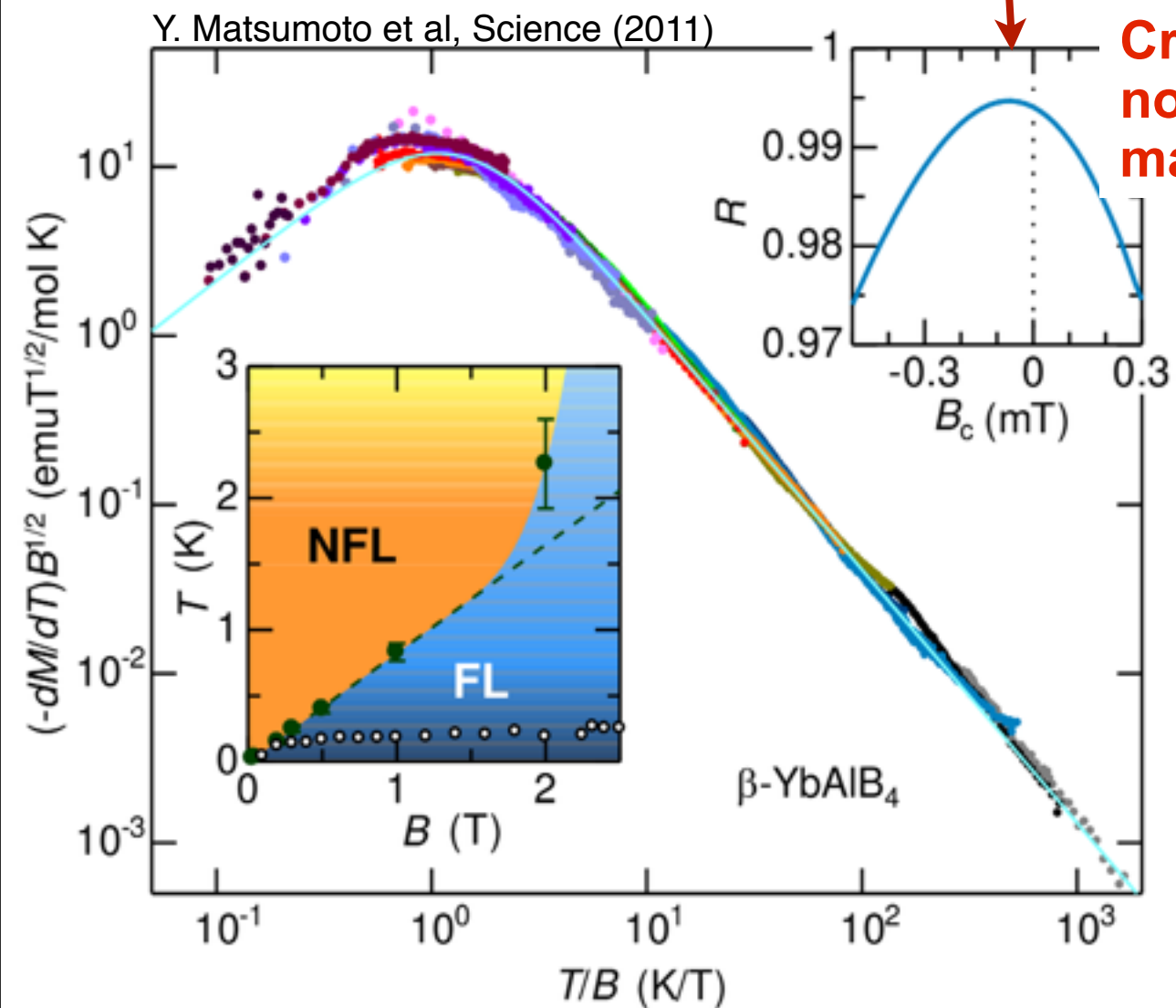


Critical field, if it exists, is no bigger than the earth's magnetic field (0.06mT)



Strange Metals.

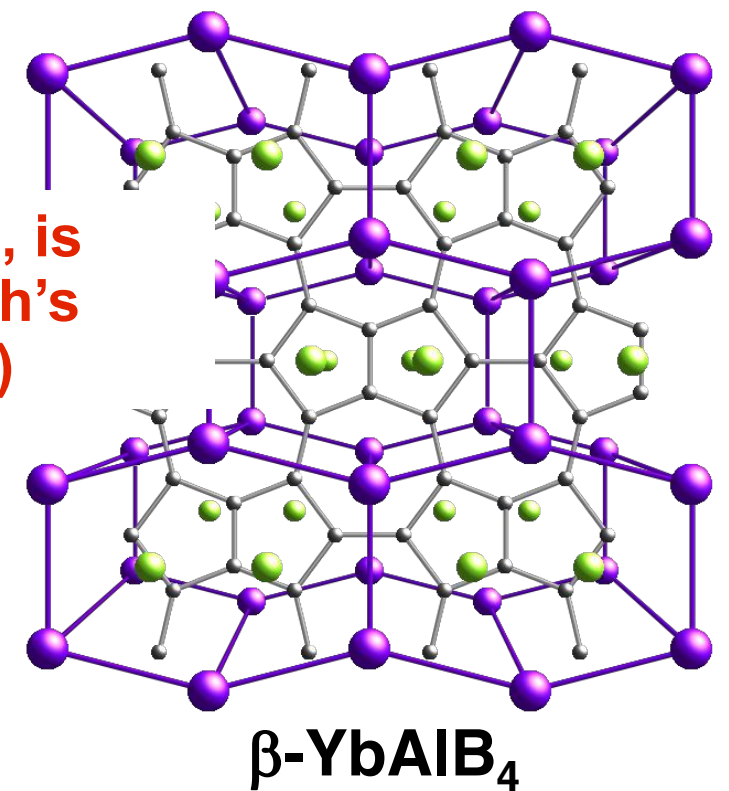
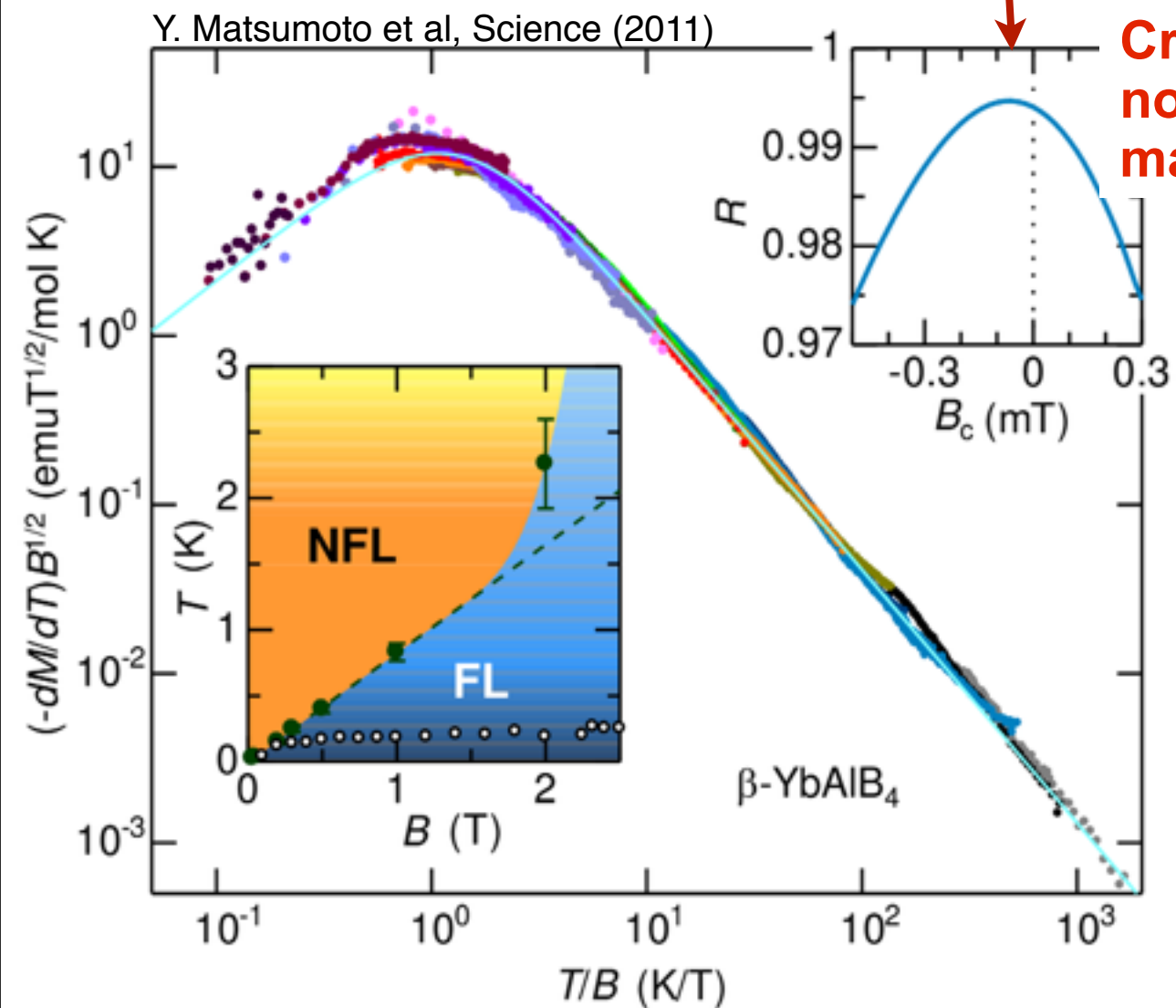
Yosuke Matsumoto



Matsumoto: Strange metal phase or QCP?

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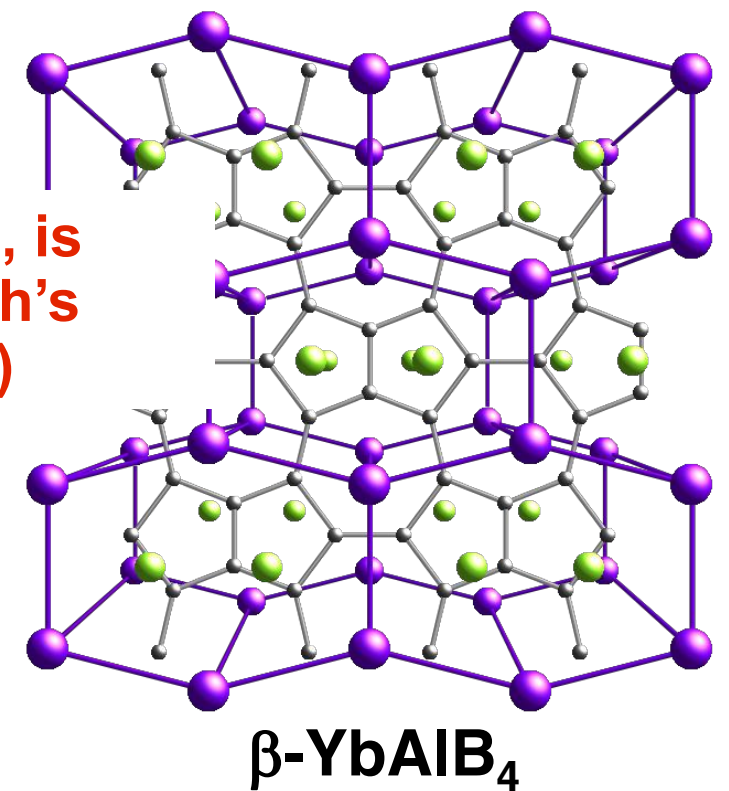
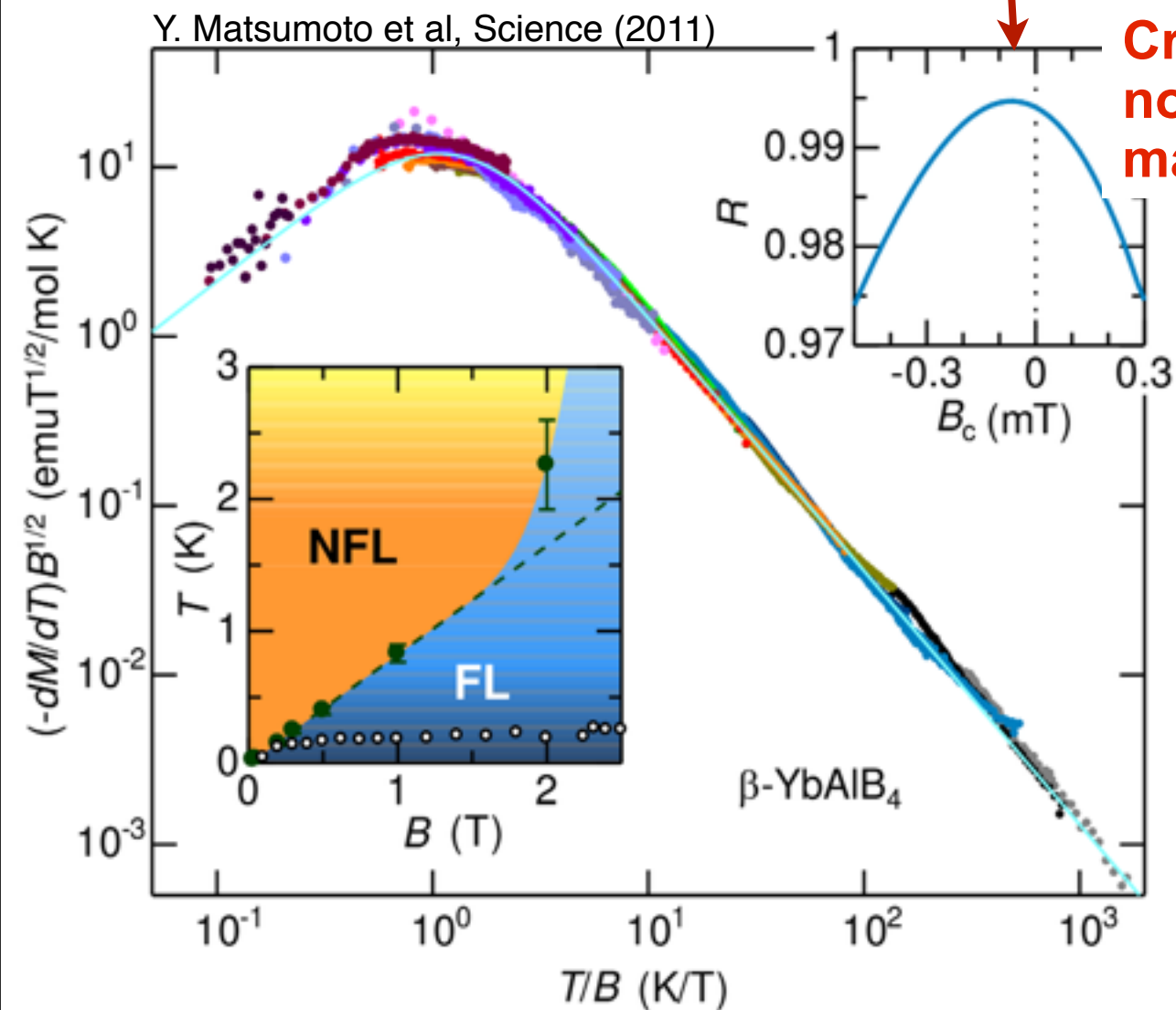


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$$N(0) \sim \frac{1}{\sqrt{B}} \quad \text{Failed Kondo insulator?}$$

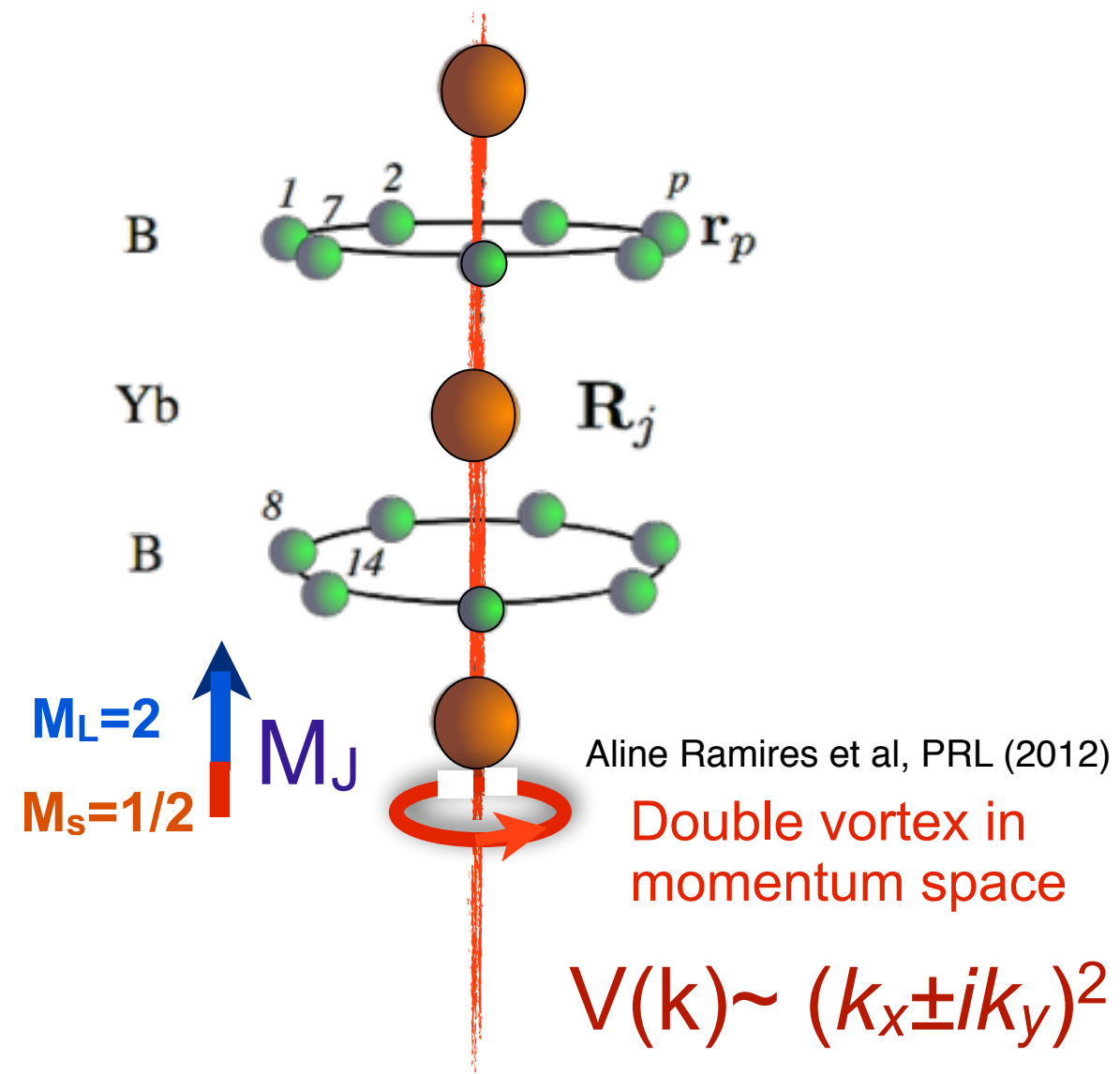
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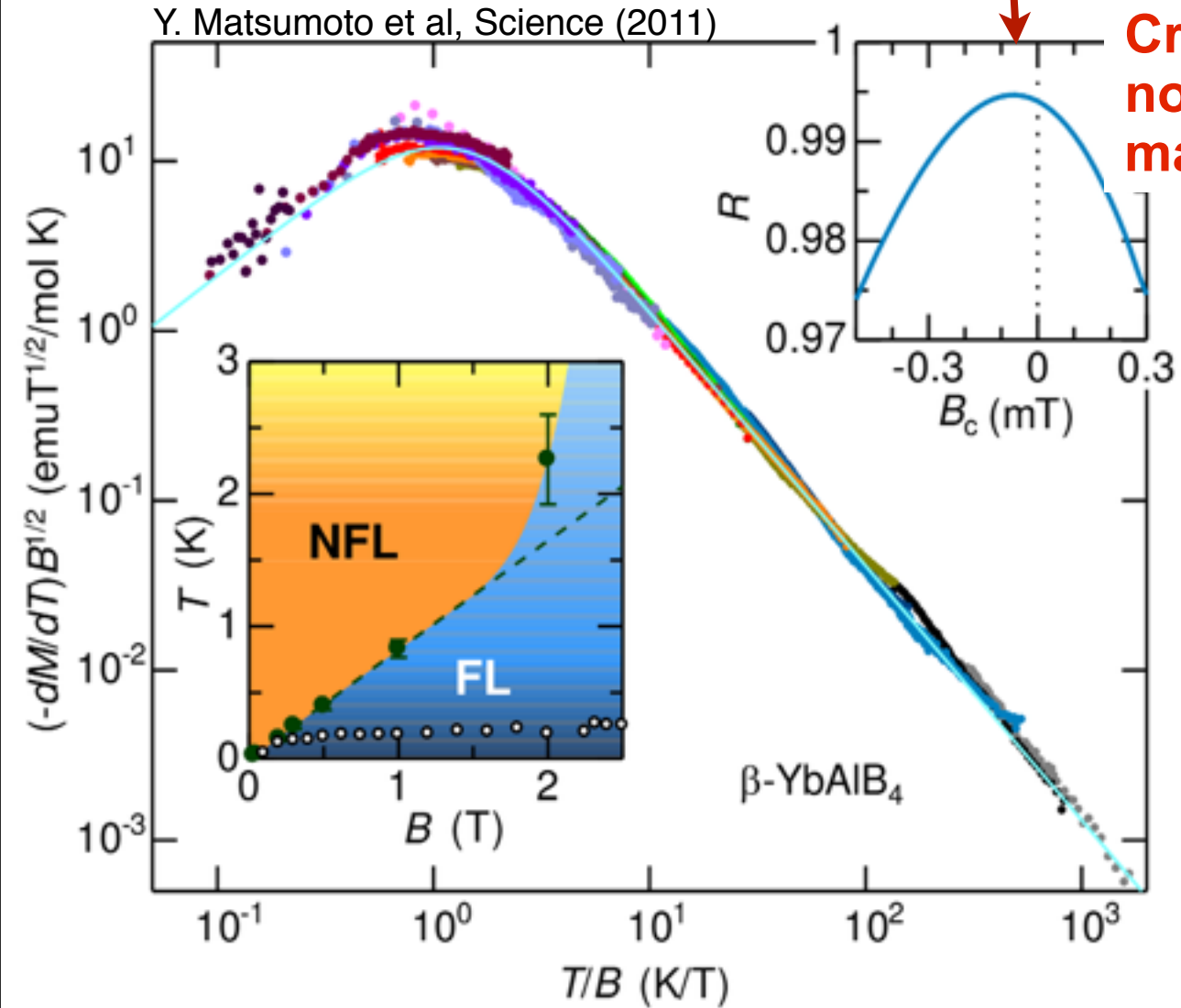
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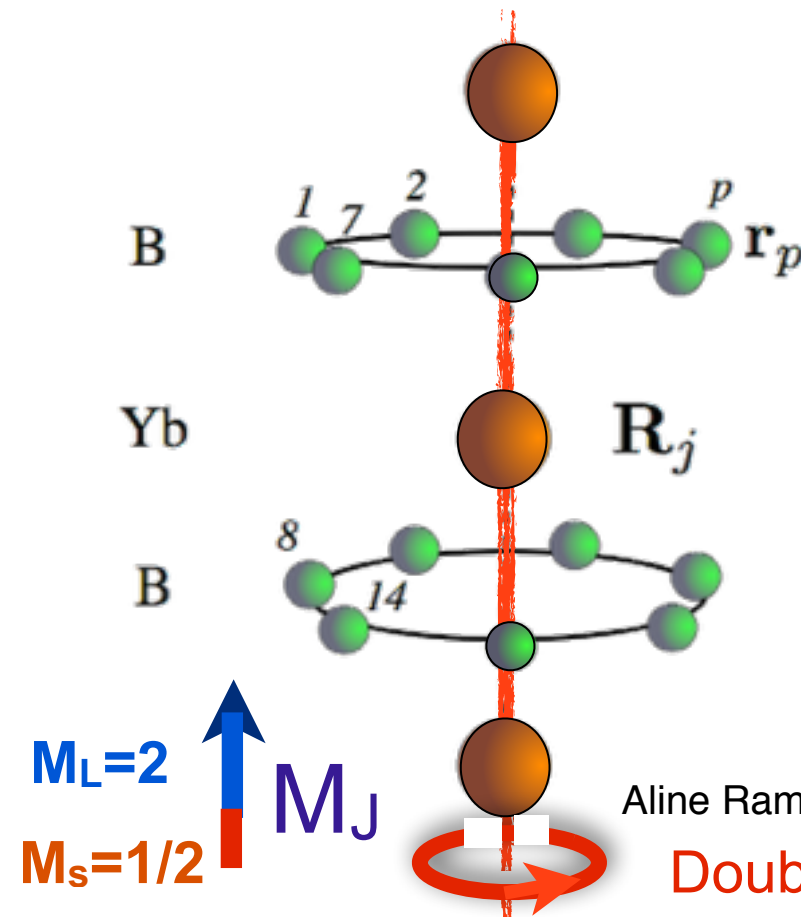
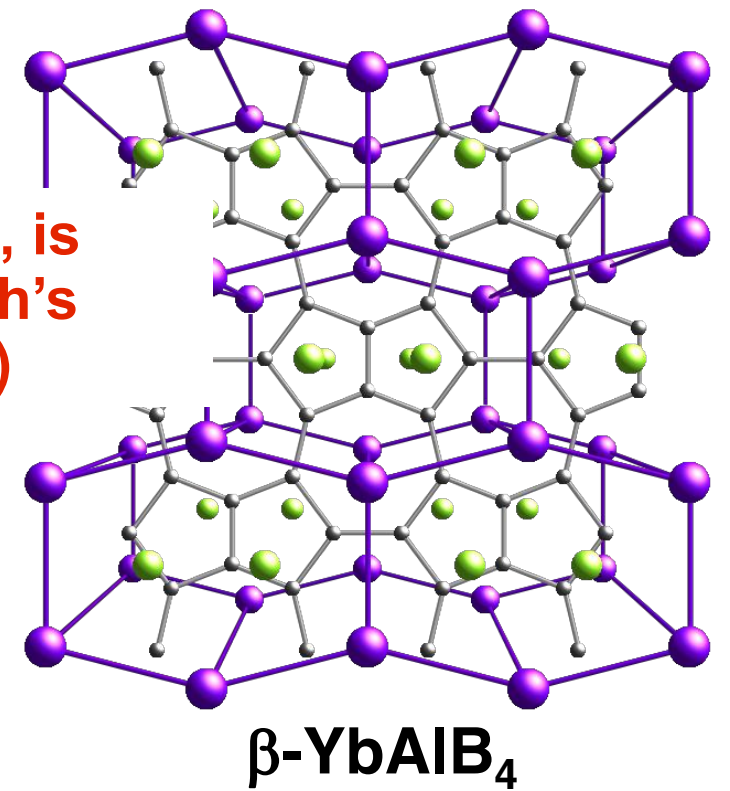


Yosuke Matsumoto

Y. Matsumoto et al, Science (2011)



Critical field, if it exists, is no bigger than the earth's magnetic field (0.06mT)



Aline Ramires et al, PRL (2012)

Double vortex in momentum space

$$V(k) \sim (k_x \pm i k_y)^2$$

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Yazdani: can one spectroscopically image the composite HF?

Yazdani: and what happens to the composite HF in a HF SC?