

INSIGHTS ON THE PSEUDOGAP IN 2D FROM AN IMPURITY MODEL

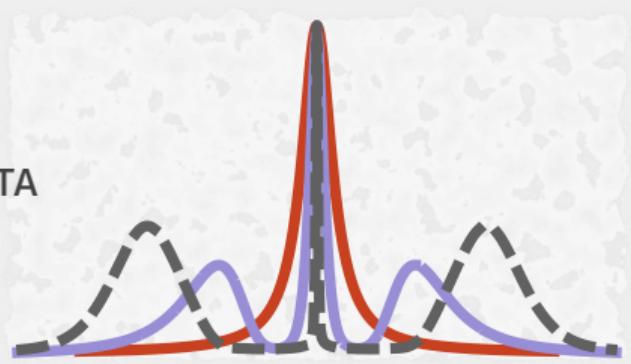
A NEW APPROACH TOWARDS CORRELATED LATTICE MODELS

ABHIRUP MUKHERJEE

DPS DAY '25

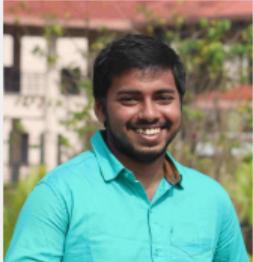
DEPARTMENT OF PHYSICAL SCIENCES, IISER KOLKATA

MARCH 19, 2025

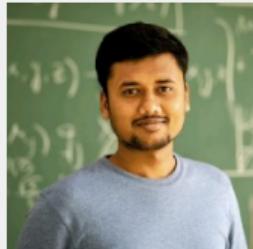




Prof. Siddhartha Lal



Debraj Debata



Siddhartha Patra
(Multiverse Computing)



Prof. Anamitra Mukherjee
(NISER Bhubaneshwar)



Prof. Arghya Taraphder
(IIT Kharagpur)



Prof. N. S. Vidhyadhiraja
(JNCASR Bangalore)

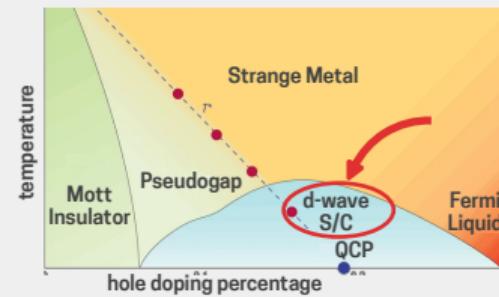
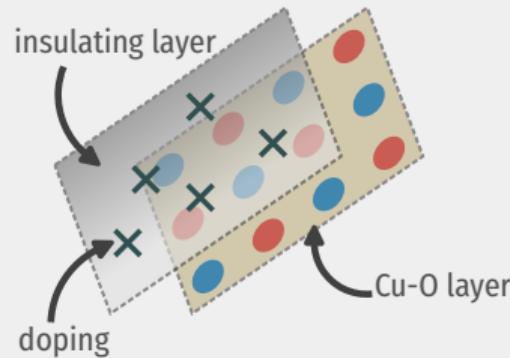


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**Financial support by IISER K and SERB is gratefully acknowledged.**  
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THE ADVENT OF QUANTUM MATERIALS: CUPRATE SUPERCONDUCTORS

Consists of **Cu-O planes** that can be doped.

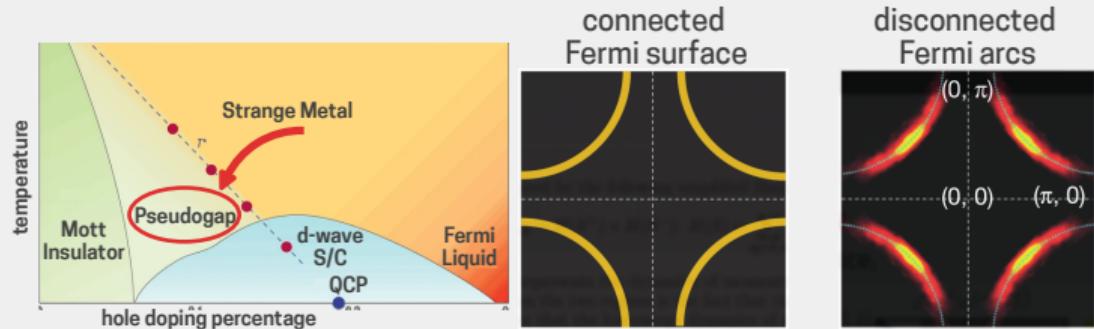
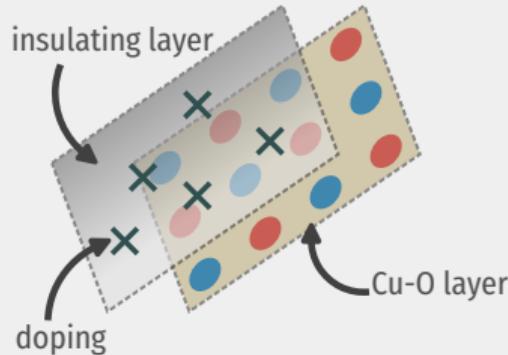
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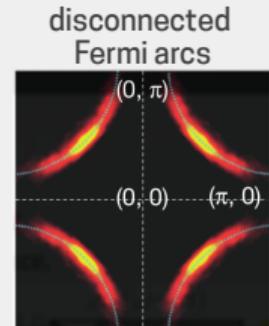
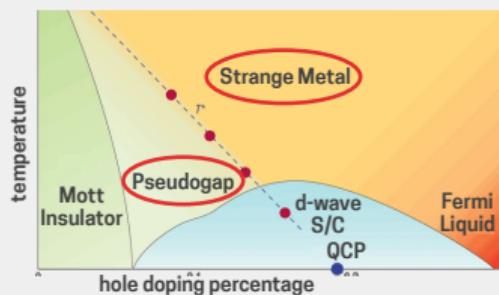
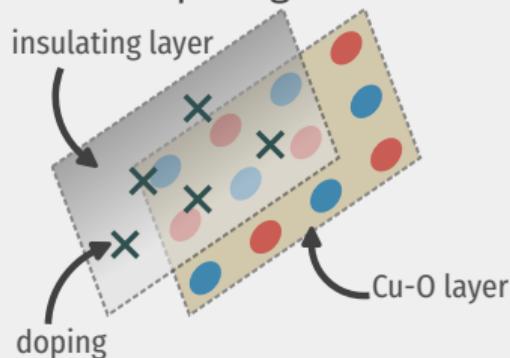
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- **Pseudogap** phase has Fermi arcs and competing fluctuations



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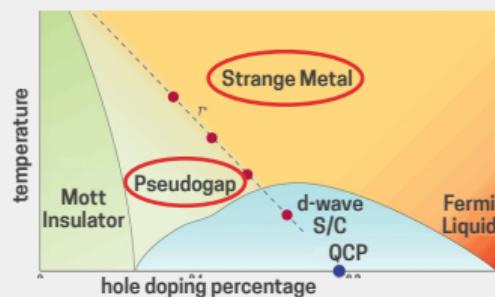
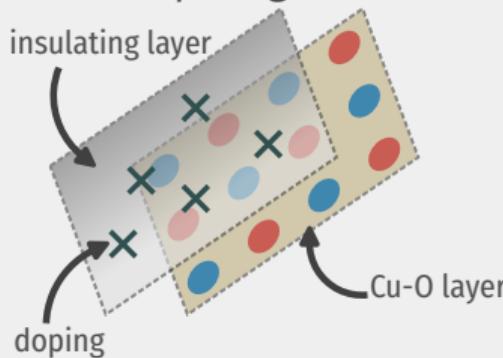
Effect of these phases at **half-filling**?

- * **Missing:** Microscopic understanding of the pseudogap phase
- * **Missing:** Simple and universal mechanism for strange metals

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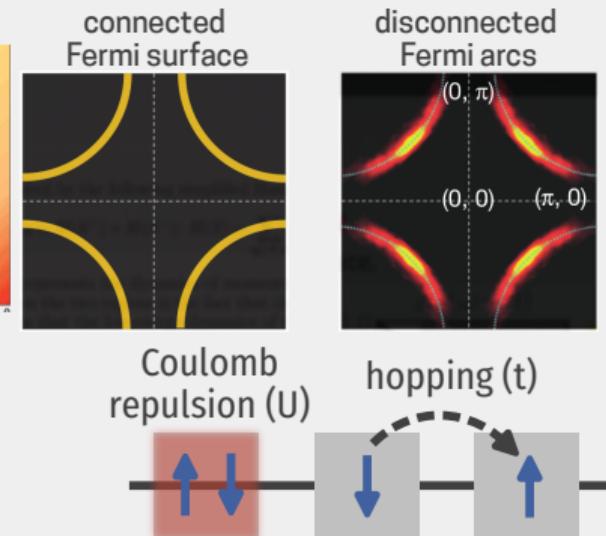


2D **Hubbard model** on square lattice

$$H = -t \sum_{\langle i,j \rangle, \sigma} (c_{i,\sigma}^\dagger c_{j,\sigma} + \text{h.c.}) + U \sum_i n_{i\uparrow} n_{i\downarrow}$$

Too hard to solve! Alternative approaches needed.

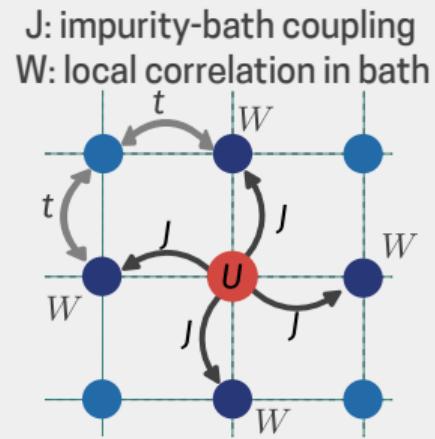
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A BOTTOM-UP APPROACH: STARTING FROM AN IMPURITY MODEL

What is an Impurity Model?

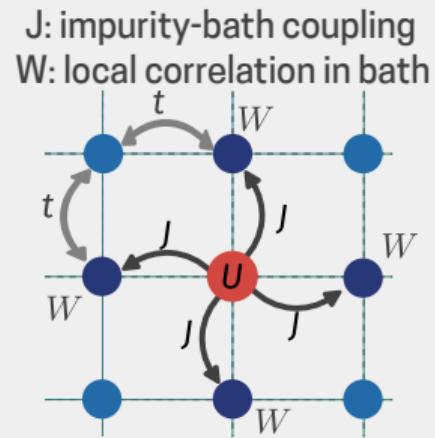
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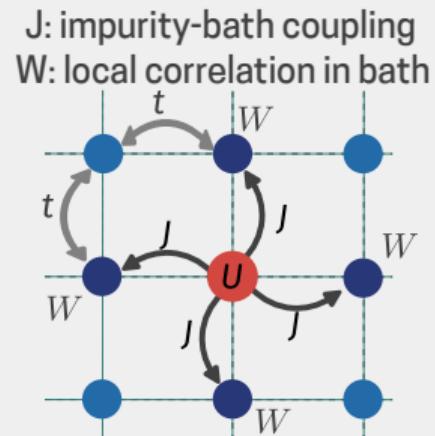
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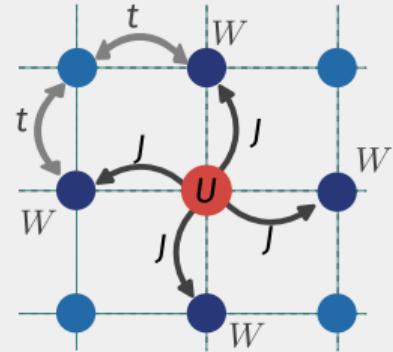


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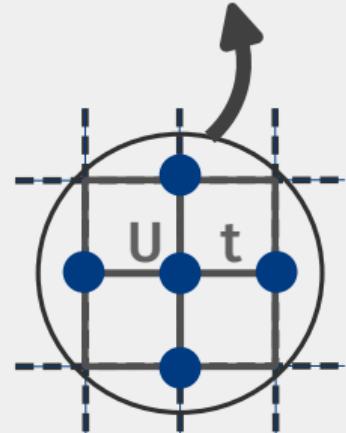
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J: impurity-bath coupling
W: local correlation in bath



Mapping to the Lattice Model

- Impurity model describes hopping into the correlated **local environment**.



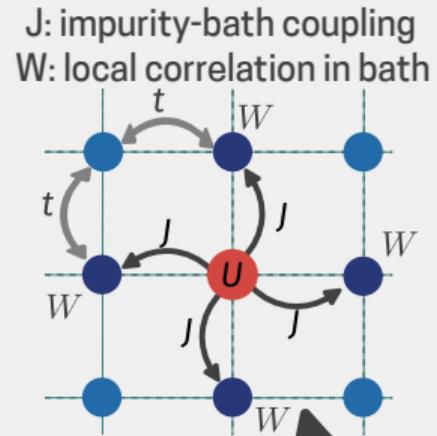
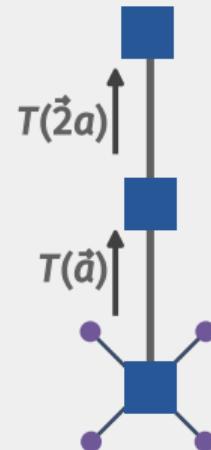
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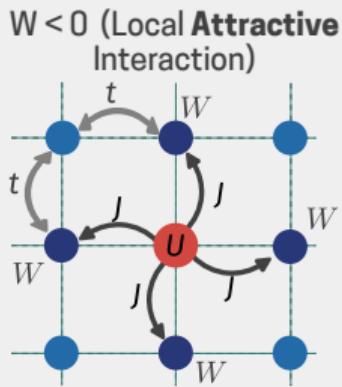
Mapping to the Lattice Model

- Impurity model describes hopping into the correlated **local environment**.
- **Translation** operator maps impurity model quantities to those on the lattice model (**Hubbard-Heisenberg** model)



MOMENTUM-SPACE RESOLVED IMPURITY PHASE TRANSITION

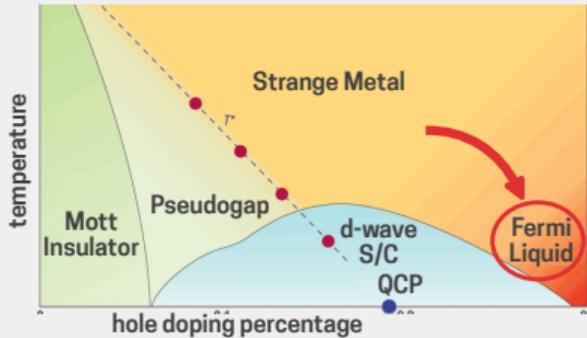
Increasing bath correlation W tunes the impurity model through three phases



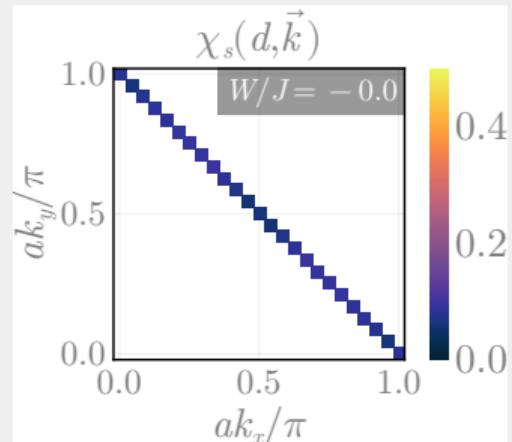
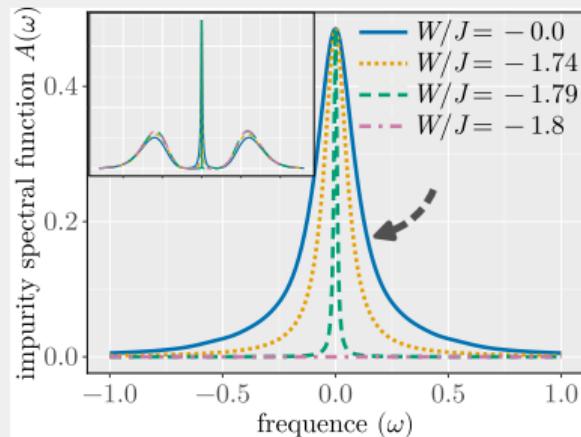
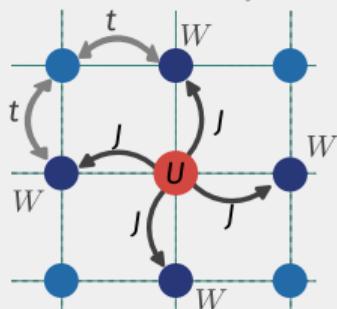
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- Impurity **strongly coupled** to Fermi surface



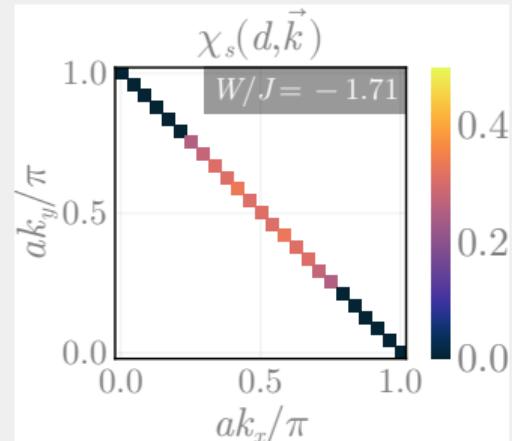
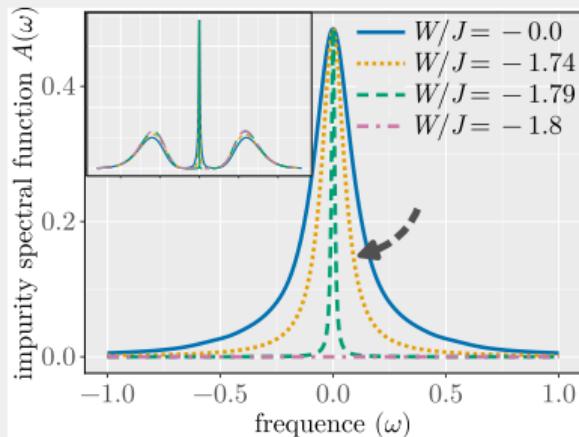
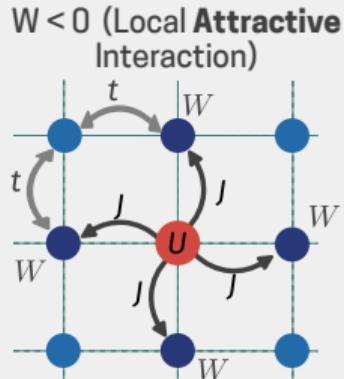
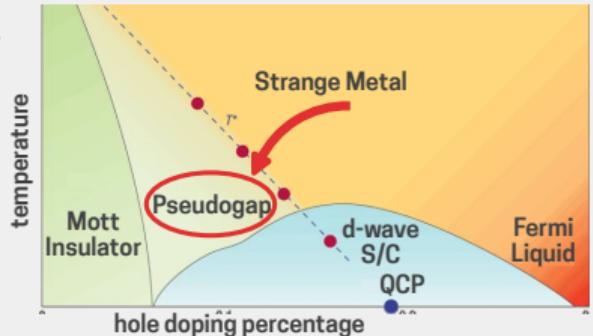
$W < 0$ (Local **Attractive** Interaction)



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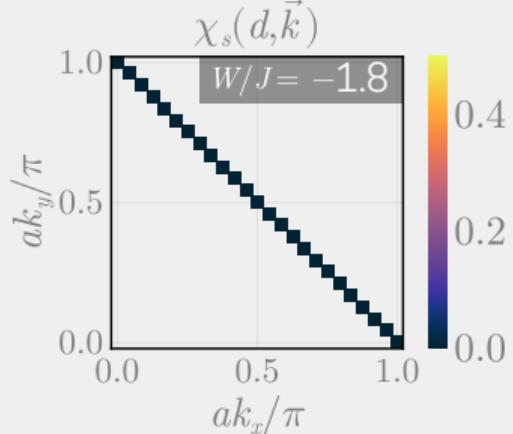
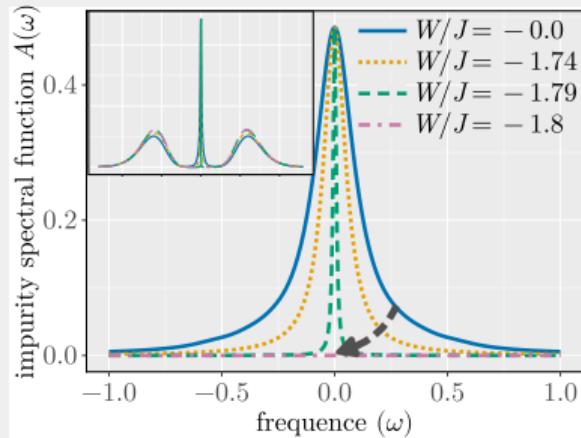
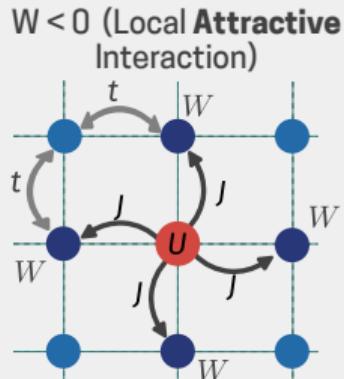
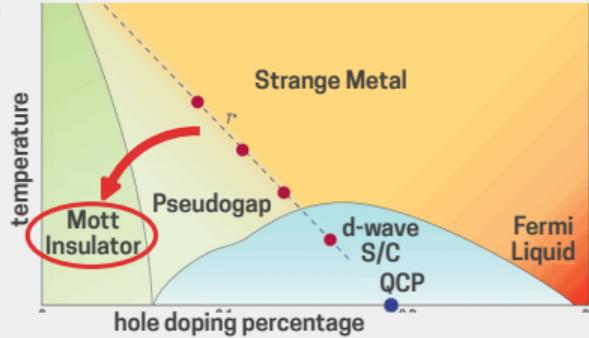
- Impurity **strongly coupled** to Fermi surface
- Impurity coupled **only to parts** of Fermi surface



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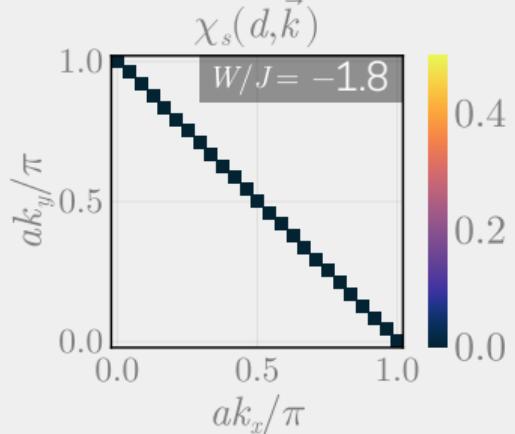
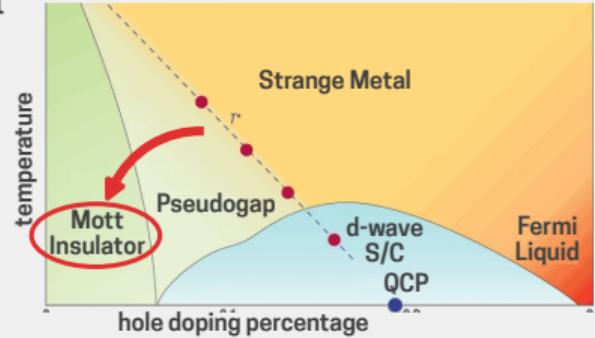
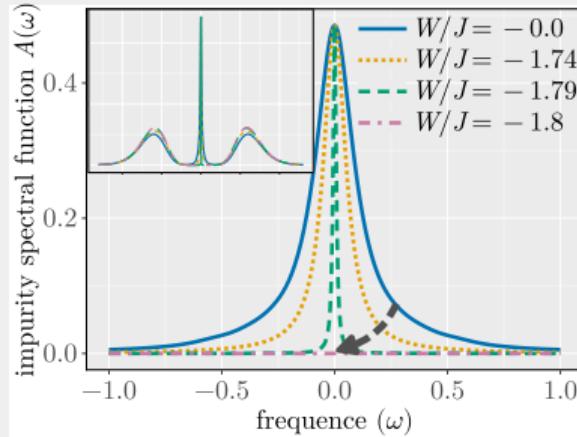
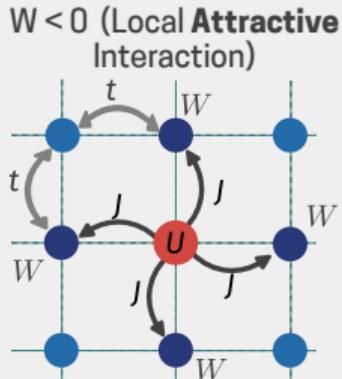
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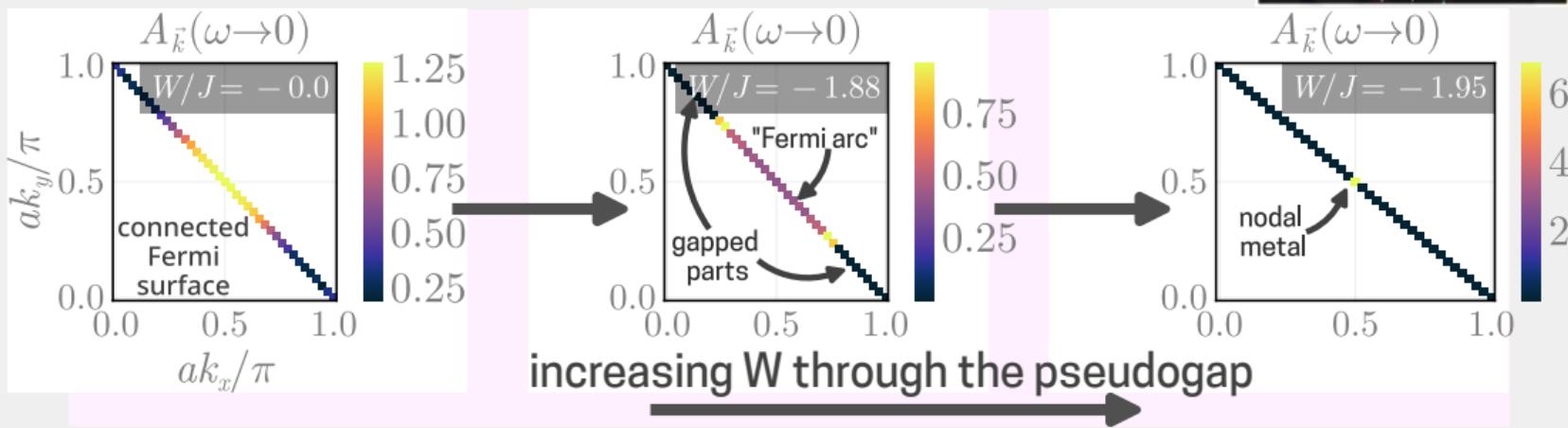
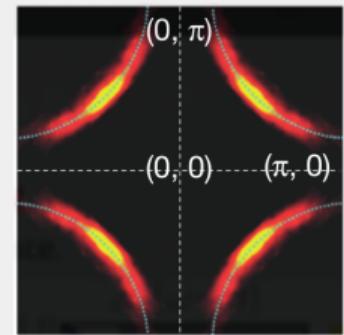
Increasing bath correlation W tunes the impurity model through three phases

- Impurity **strongly coupled** to Fermi surface
- Impurity coupled **only to parts** of Fermi surface
- Impurity **decoupled** from the Fermi surface
- Spectral function **sharpens** as Fermi surface decouples.



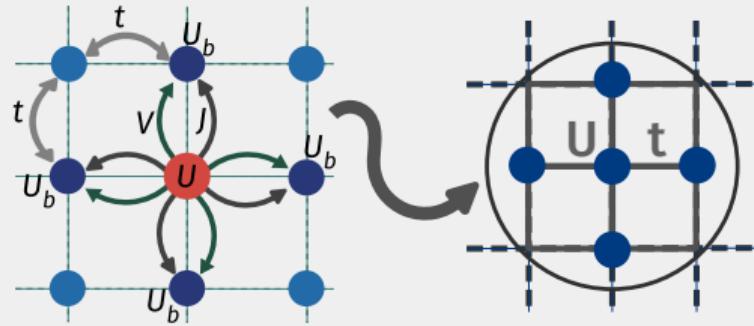
PSEUDOGAPPING TRANSITION ON THE LATTICE MODEL

- Map Greens functions from impurity model to **lattice model**.
- Momentum-space DOS reveals **partially gapped** Fermi surface.



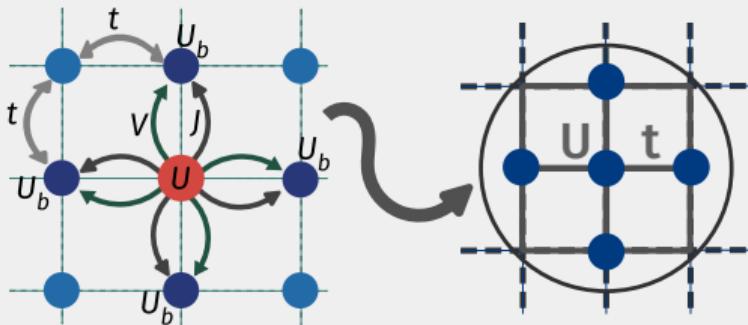
MAIN TAKEAWAYS

Our approach **simplifies** study of lattice models via appropriate **impurity models**.

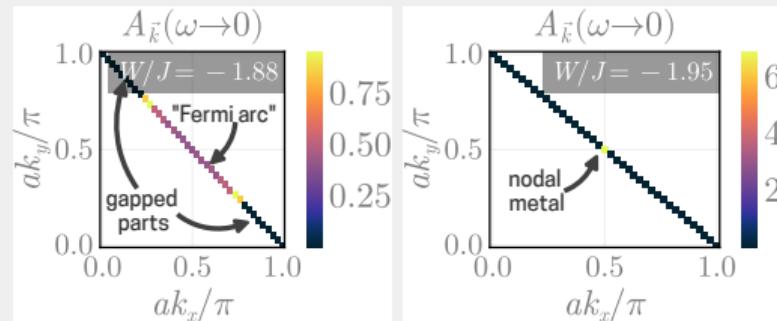


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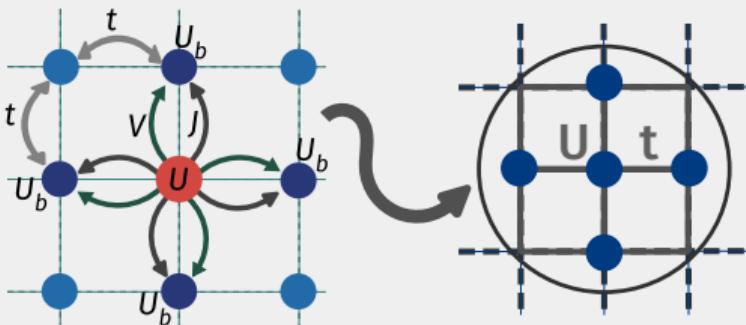


Our impurity model realises a **pseudogap-ping transition** in a correlated model.

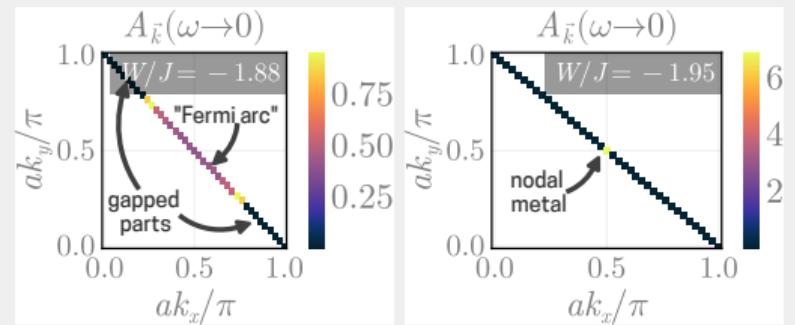


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Generalisations and Extensions

- Tune impurity filling - simulate **doping!**
- Multiple impurities - symmetry-broken or **spin liquid** phases

