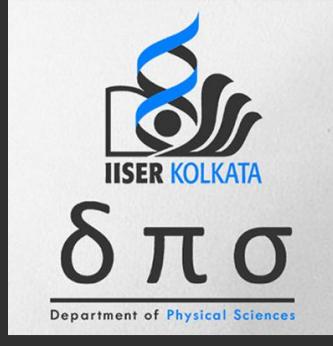


Unitary RG Approach to Quantum Impurity Problems

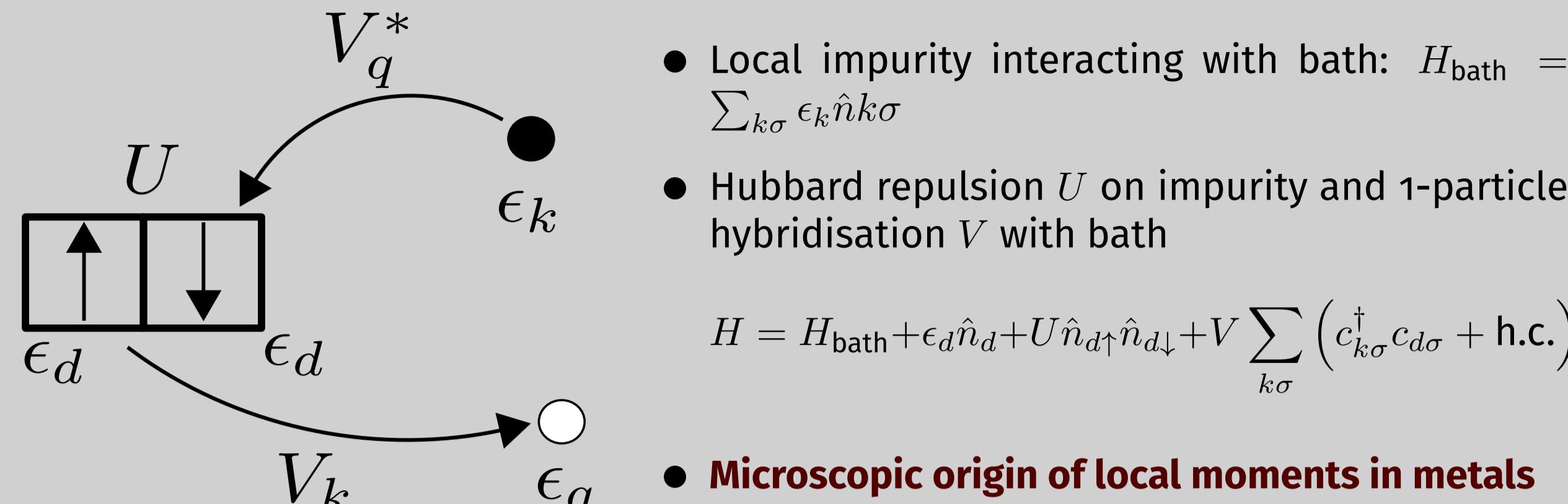
[1] Department of Physical Sciences, IISER Kolkata



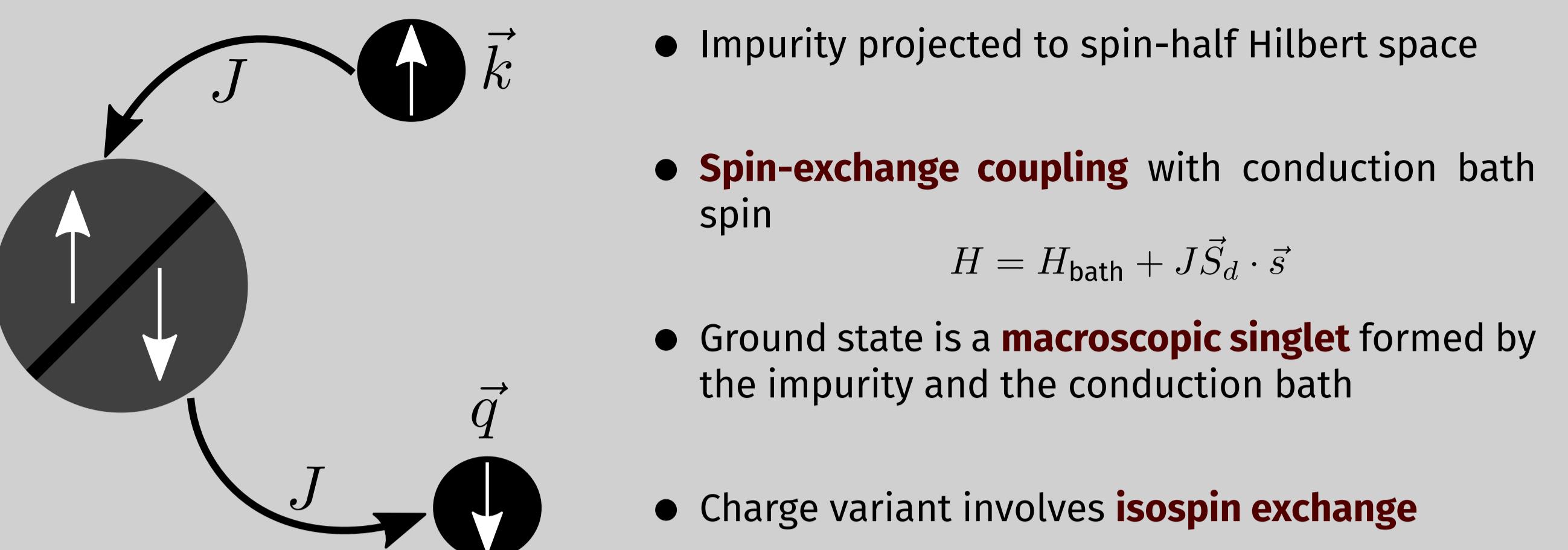
Phys. Rev. B 105, 085119 Anirban Mukherjee^[1], Abhirup Mukherjee^[1], N.S. Vidhyadhiraja^[2], A. Taraphder^[3], Siddhartha Lal^[1]

[2] Theoretical Sciences Unit, JNCASR [3] Department of Physics, IIT Kharagpur

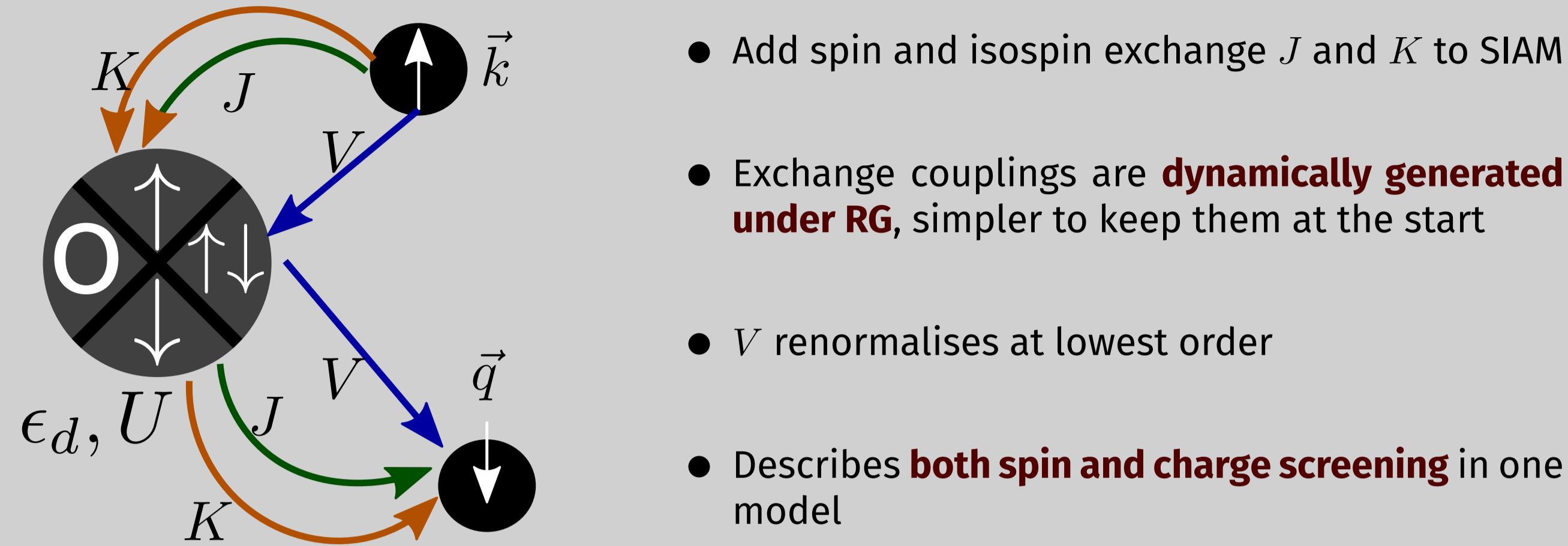
The Anderson impurity model (SIAM)



The Kondo model



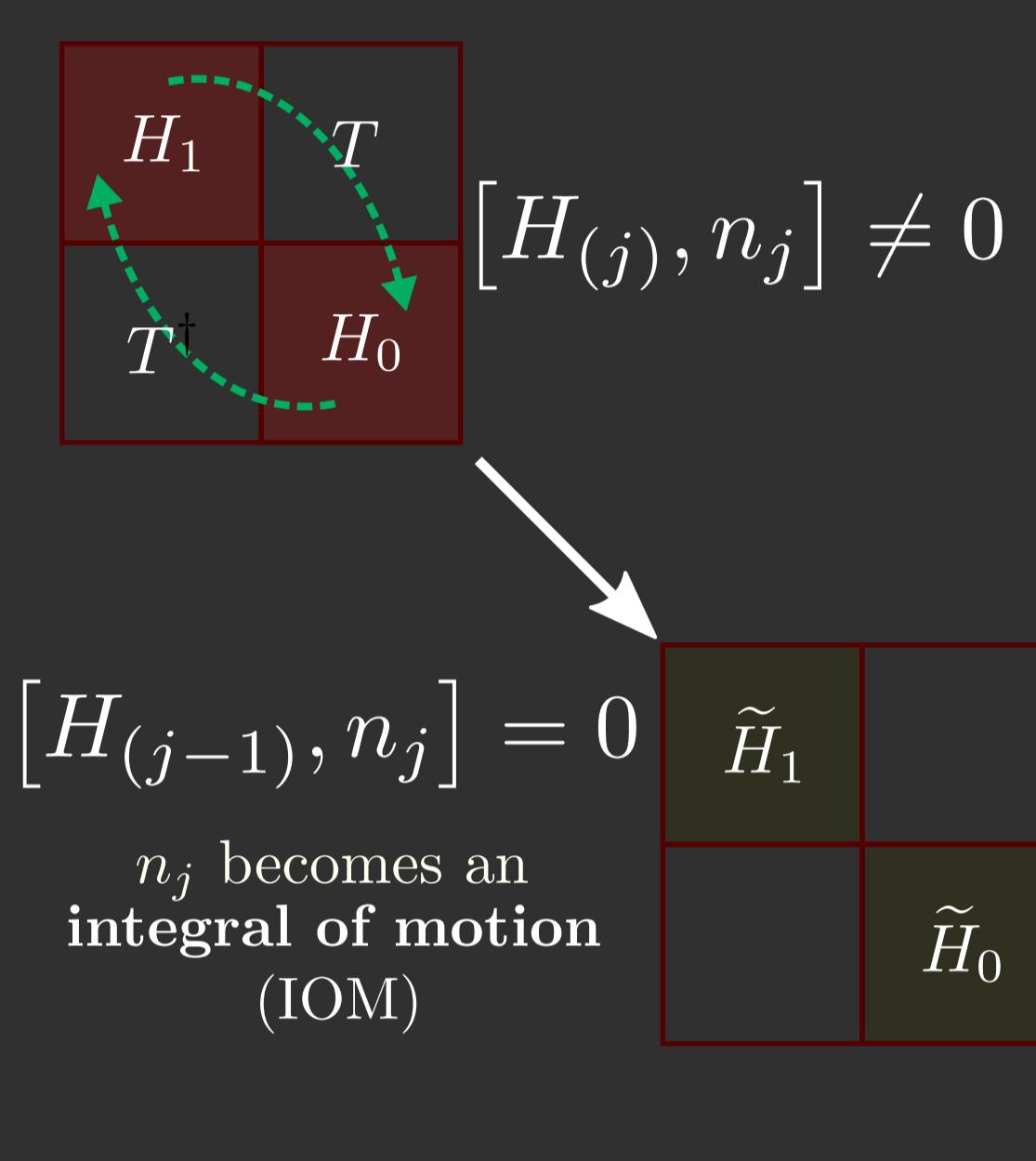
Generalised Kondo-SIAM model



Outstanding Questions

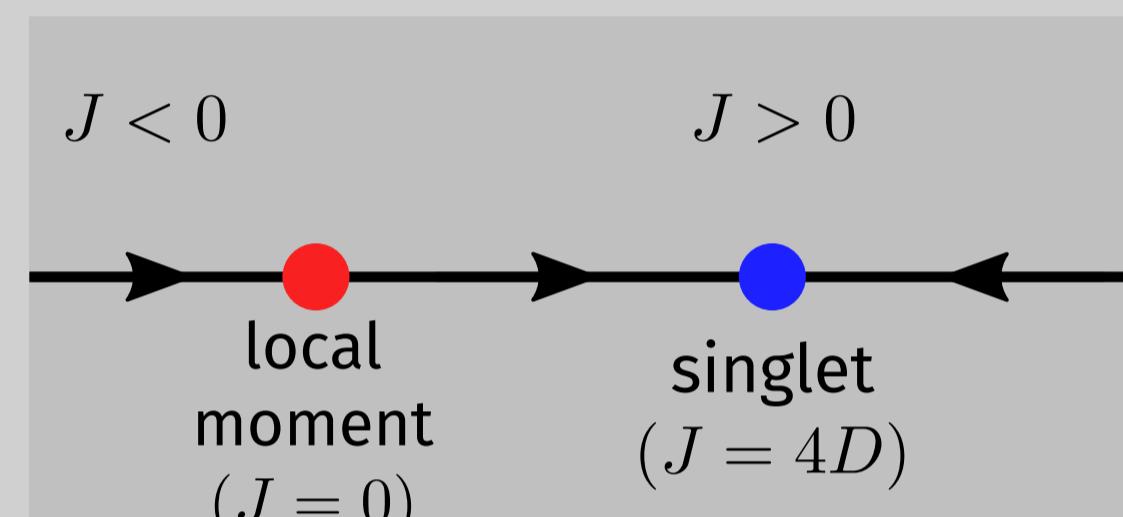
- What's the **effective Hamiltonian** for the conduction electrons that screen the impurity?
- What is the **nature of the metal** responsible for this screening?
- Quantitative insight into **many-particle entanglement** at and near the fixed point
- Does the interplay of V , J and K change the phase diagram in the generalised SIAM?
- Is there any **topological quantity** that changes in the process of screening?
- Can we track the **evolution of the impurity spectral function** along the RG flow?

The Unitary Renormalisation Group (URG) Method



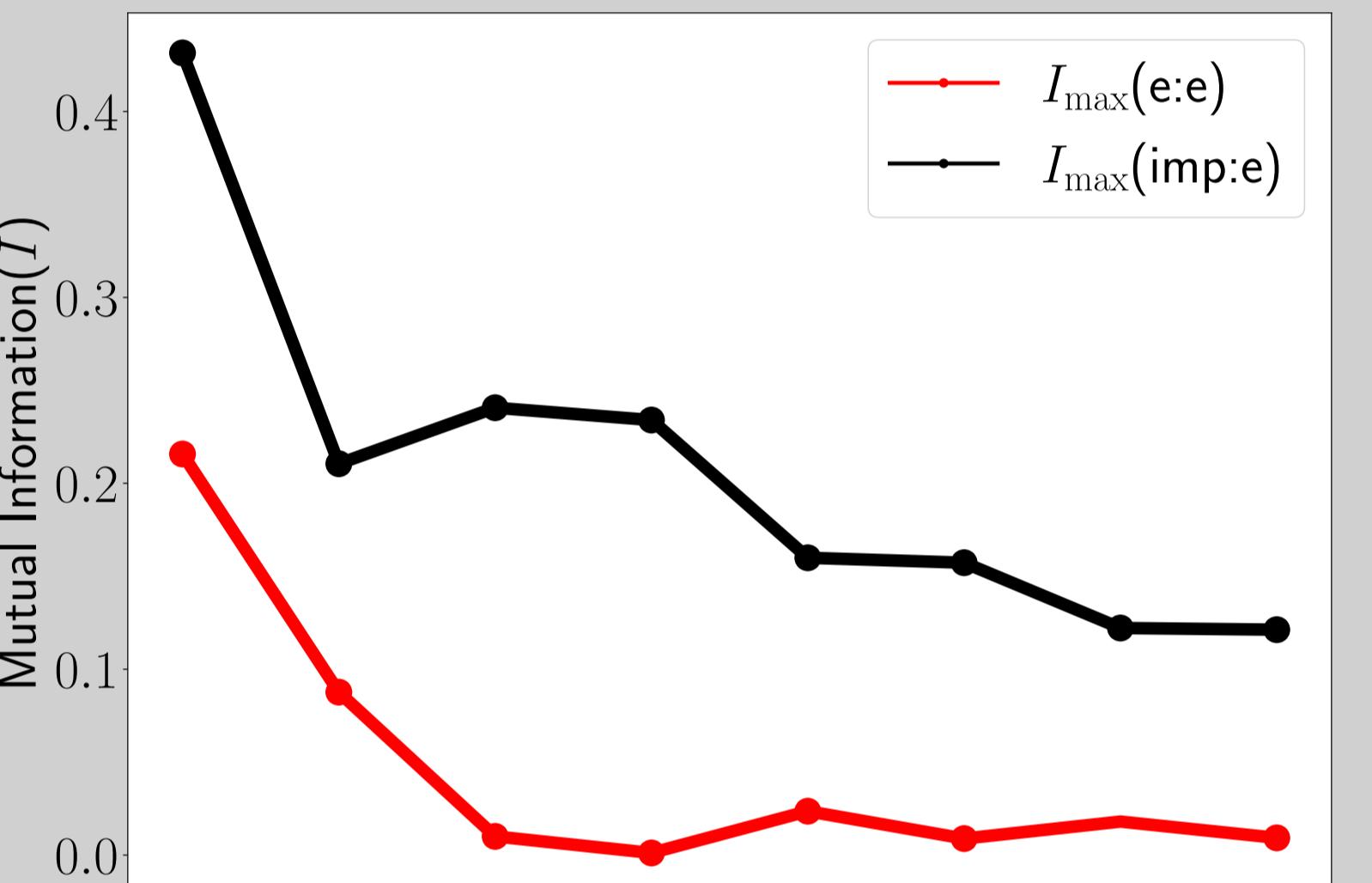
- Proceeds by **applying unitary transformations** U_j on the Hamiltonian to generate RG flow H_j
 $H_{j-1} = U_j H_j U_j^\dagger$
- U_j are defined so as to **remove quantum fluctuations** of high energy k -states
- Continues until denominator of RG equation vanishes: **fixed point**
- Fixed point Hamiltonian describes **emergent theory** at low energy

URG Flows of the Kondo Model: Phase Diagram



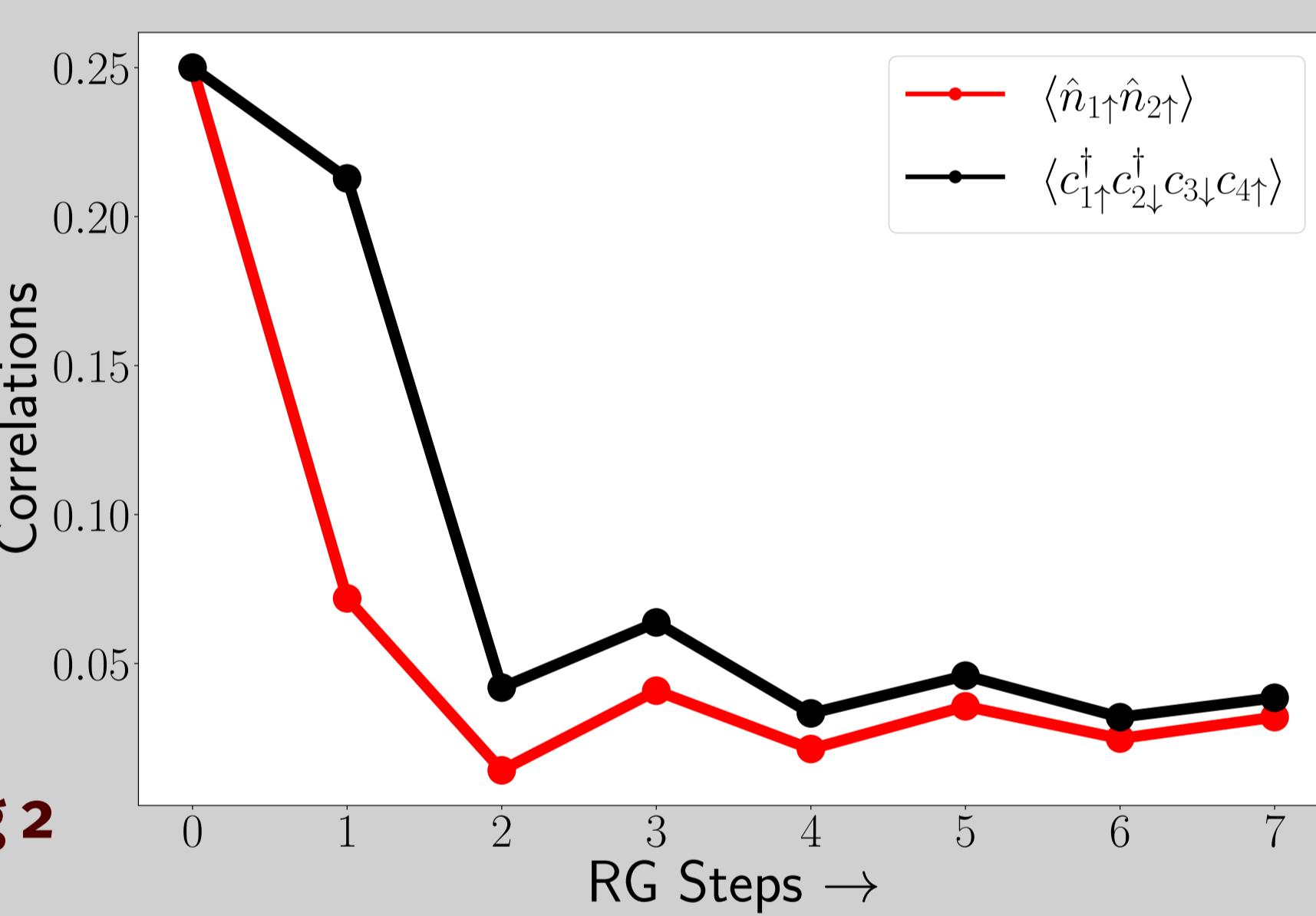
- $J = 0$ is stable for $J \leq 0$: **local moment** fixed point
- $J = 2D$ is globally stable: **strong-coupling** fixed point

RG Evolution of Entanglement in Kondo cloud



Mutual Information:
 $I(1 : 2) = S(1) + S(2) - S(1, 2)$
 $S(1)$ - entanglement entropy of 1

Information obtained about 1, on measuring 2

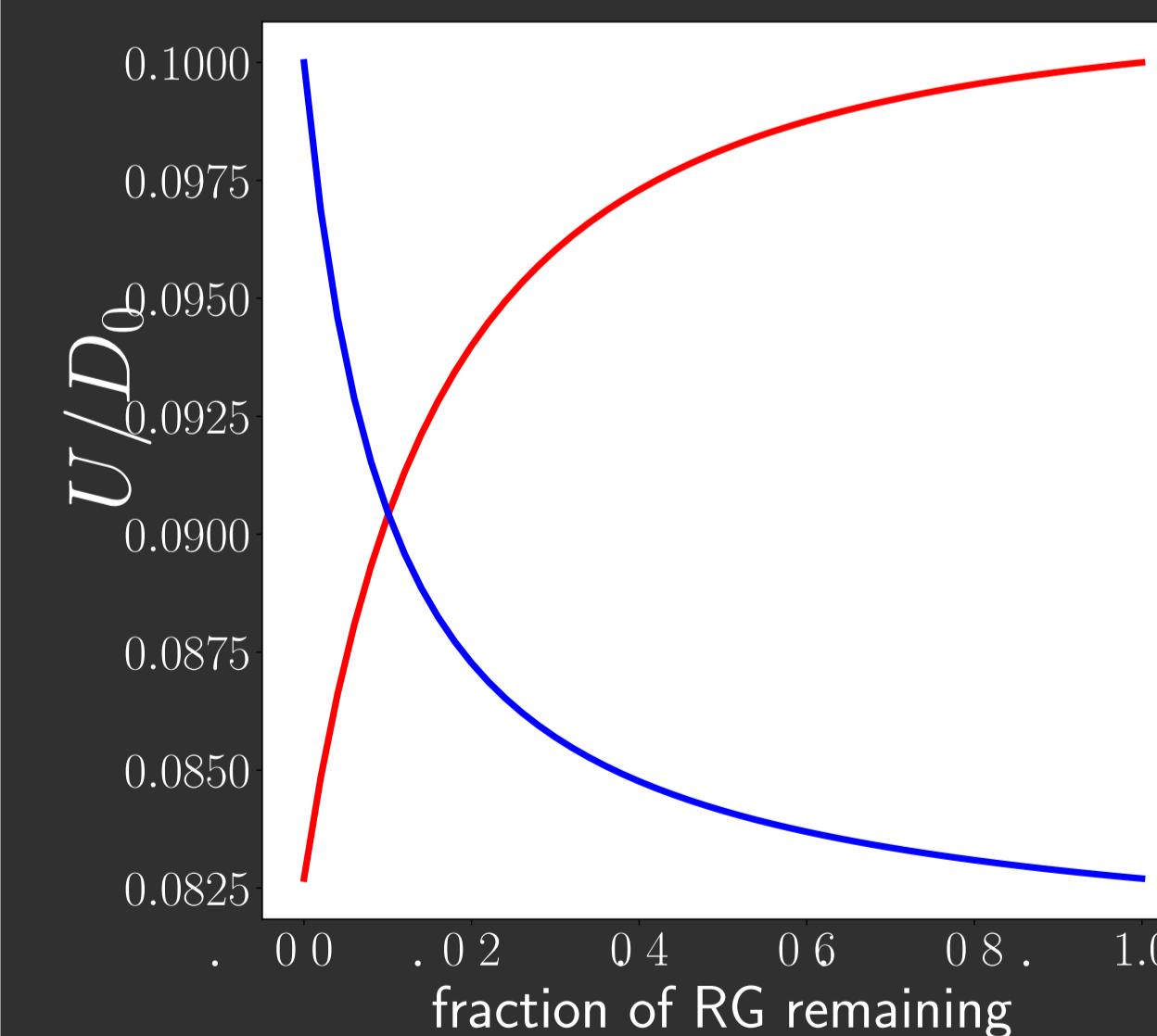


- Mut. Info. and correlations grow** towards strong-coupling IR fixed point

- Demonstrates the screening of impurity and formation of the singlet

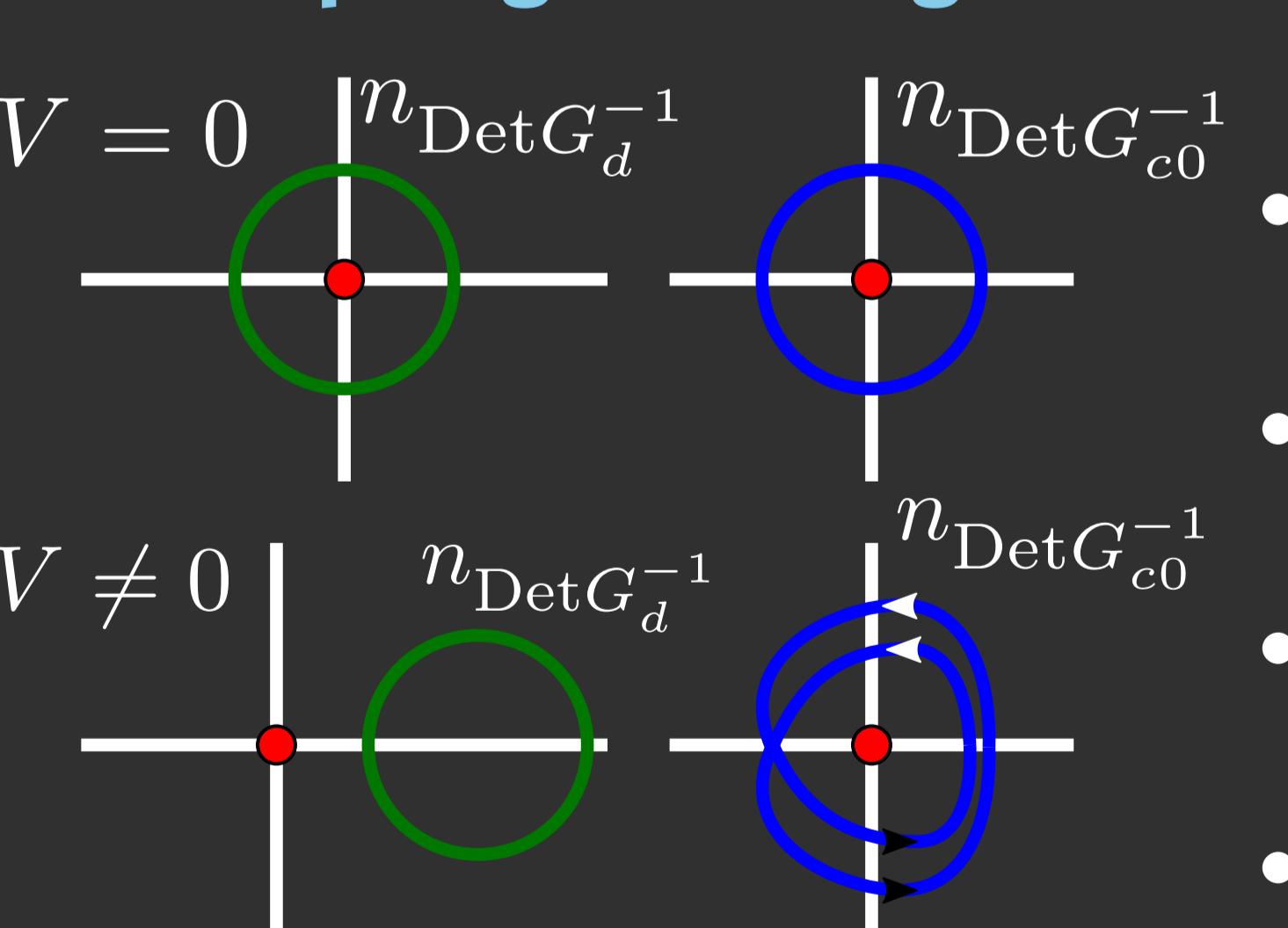
- Consistent with the **presence of non-FL terms** in Kondo cloud Hamiltonian

RG Flows of the Gen. SIAM, Effective Hamiltonian



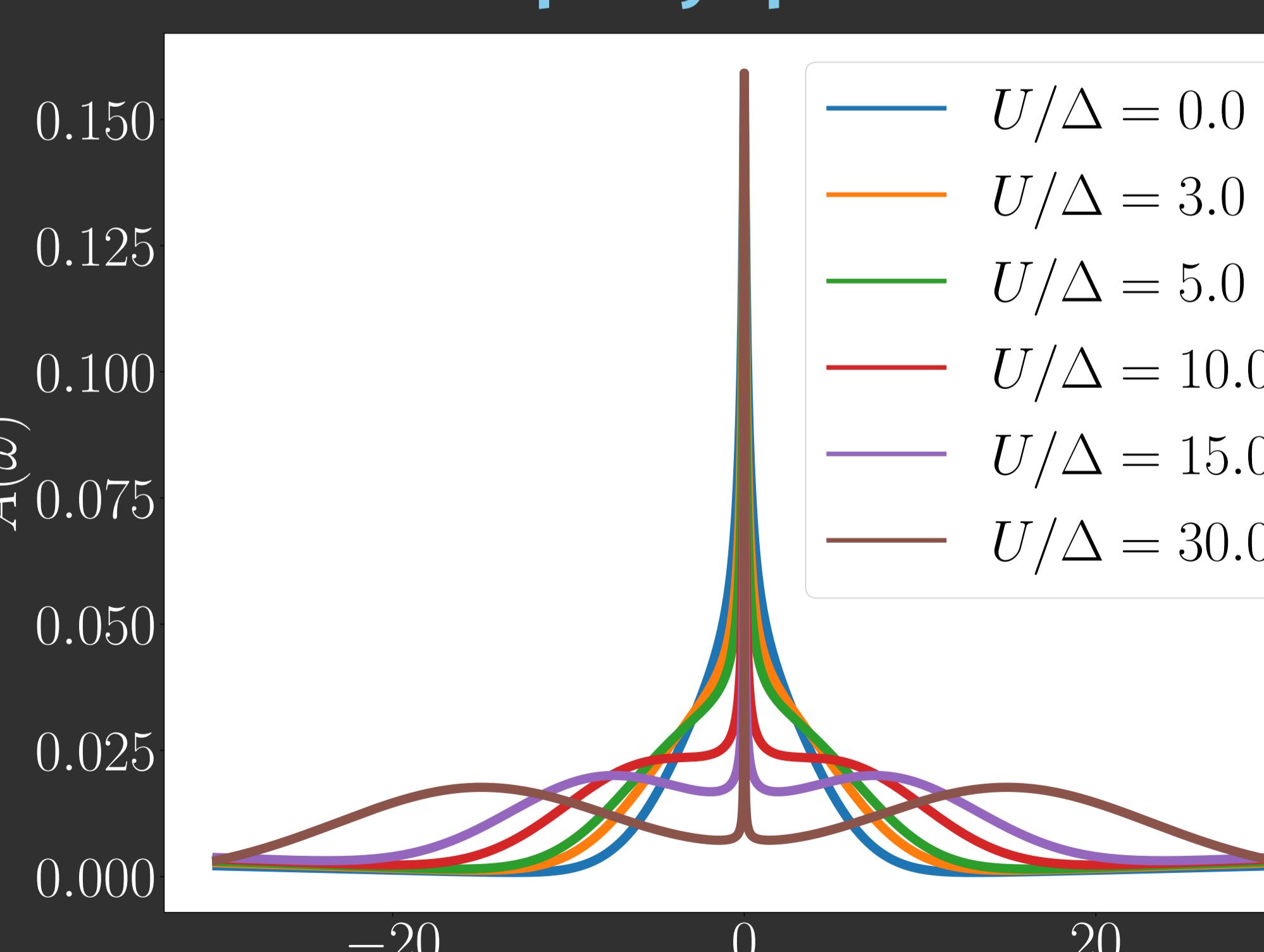
- J, V flow to strong-coupling, U may be relevant if $J > V$
- Ground state is **mixture** of spin-singlet and charge-triplet-zero
- Effective Hamiltonian of Kondo again features **non-Fermi liquid** terms
- Quantities computed from fixed point Hamiltonian **agree quantitatively** with the literature

Topological change: Increase in Luttinger's volume



- Total number of electrons is given by **Luttinger's volume** (LV)
- At strong-coupling fixed point, impurity hybridises with the impurity
- This leads to an **increase in the topological quantity** LV by 1
- A pole is transferred** from the impurity Greens function to the bath Greens function

Evolution of Impurity Spectral Function



- Impurity spectral function obtained from effective Hamiltonian
- Single broad central peak at $J, V \gg U \rightarrow$ low-energy scattering
- Side peaks appear at $J, V \ll U$, representative of local moment

Future Directions

- Self-energy calculation of the complete cloud should reveal the type of non-Fermi liquid
- Enhance gen. SIAM to stabilise local moment - **metal-insulator transition** of DMFT
- More rich physics can be obtained from the lattice versions of the models

Acknowledgements

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