

Manipulation of Majorana Modes in Double Quantum Dots



Jesús David Cifuentes[†], Luis Dias da Silva
Instituto de Física, Universidade de São Paulo
jesuscif@if.usp.br

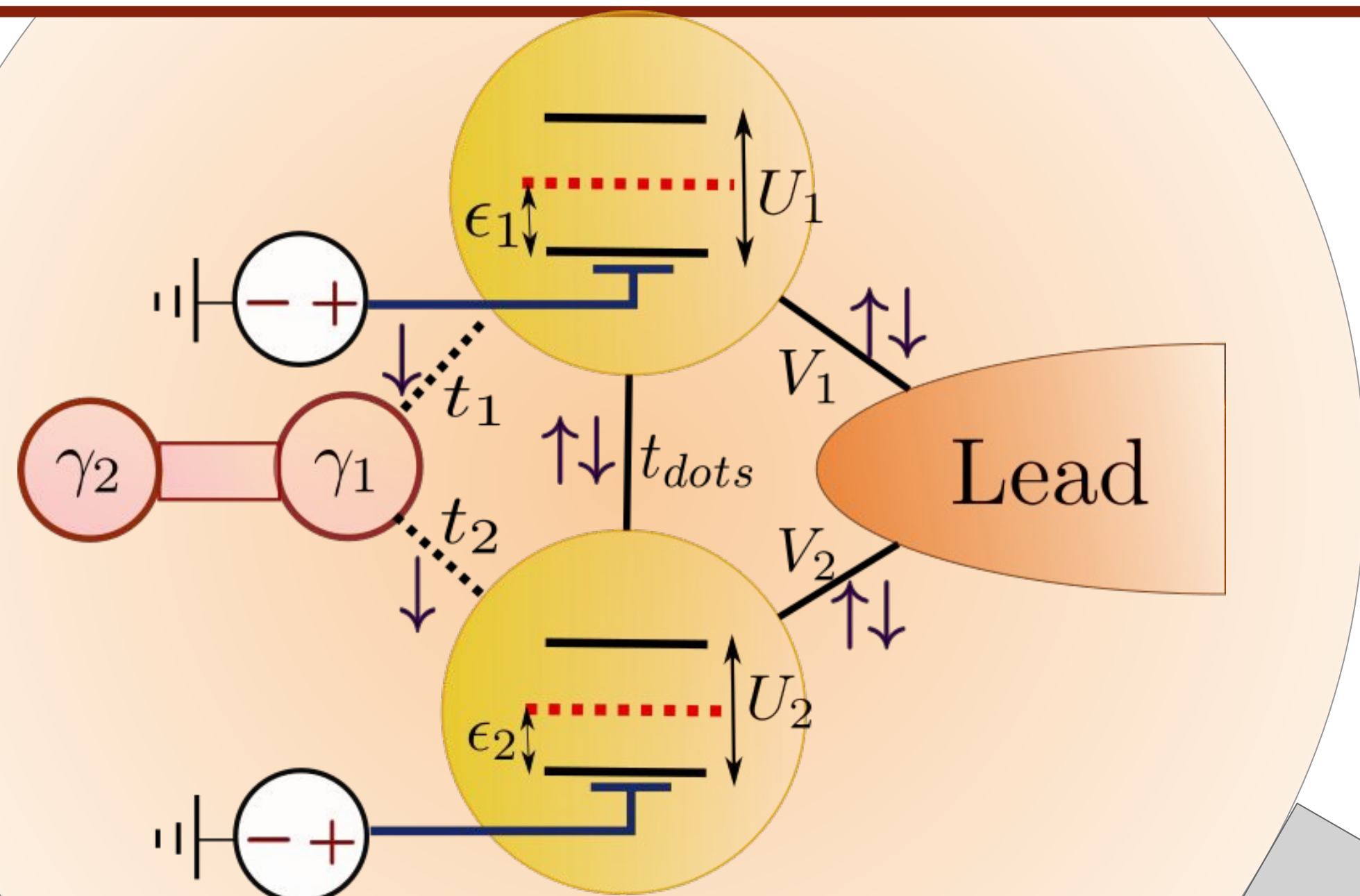


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Model

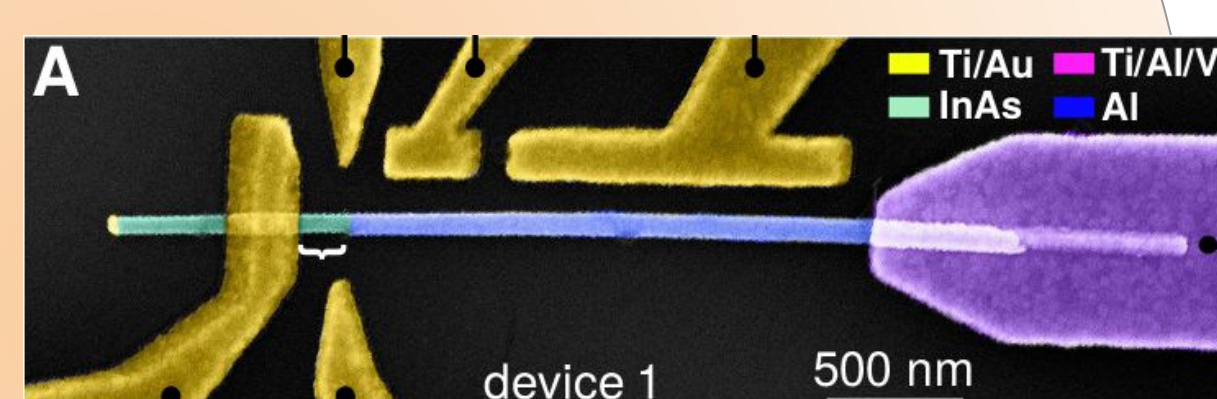
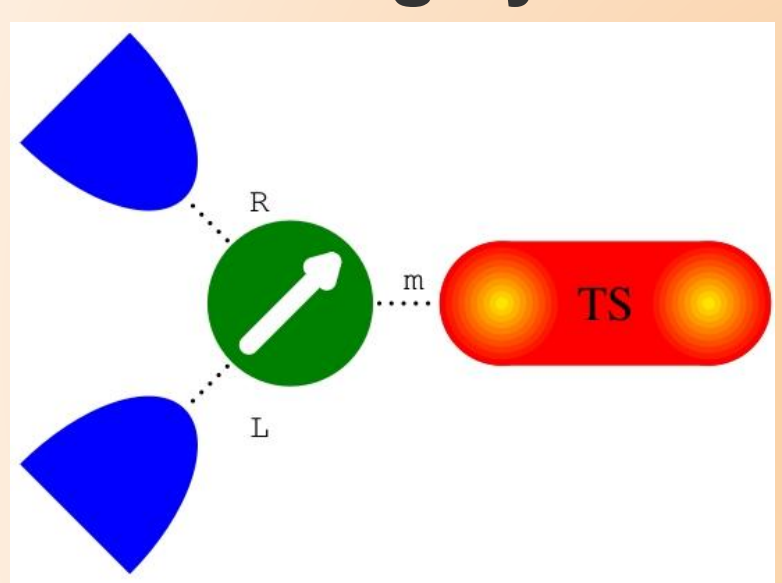
We study the electronic transport in a Double Quantum Dot (DQD) coupled to metallic leads and to a Majorana chain.

$$H = \sum_{i=1}^2 \sum_{k,\sigma} \left(\epsilon_i + \frac{U_i}{2} \right) d_{i\sigma}^\dagger d_{i\sigma} + \frac{U_i}{2} (d_{i\sigma}^\dagger d_{i\sigma} - 1)^2 + t_i \gamma_1 d_{i,\downarrow} + t_i^* d_{i,\downarrow}^\dagger \gamma_1 + V_i d_{i\sigma}^\dagger c_{k\sigma} + V_i^* c_{k\sigma}^\dagger d_{i\sigma}.$$

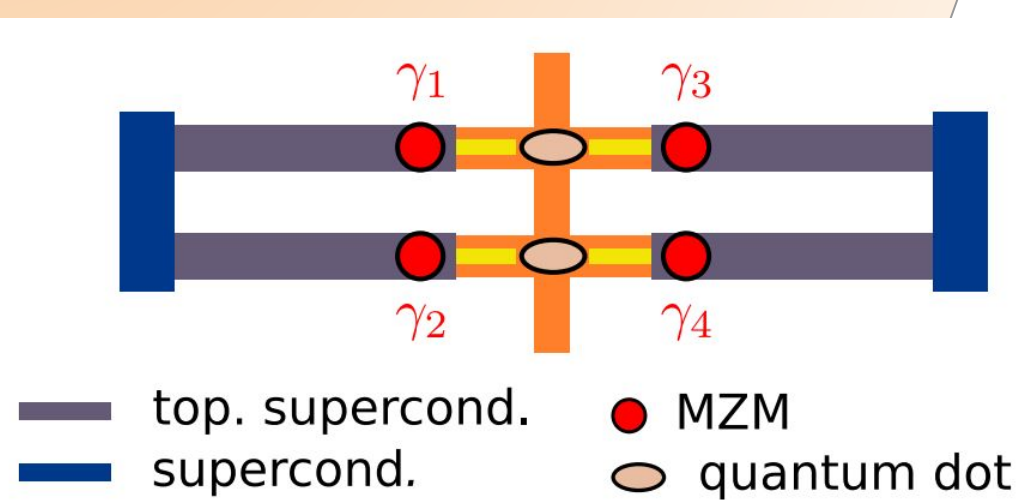
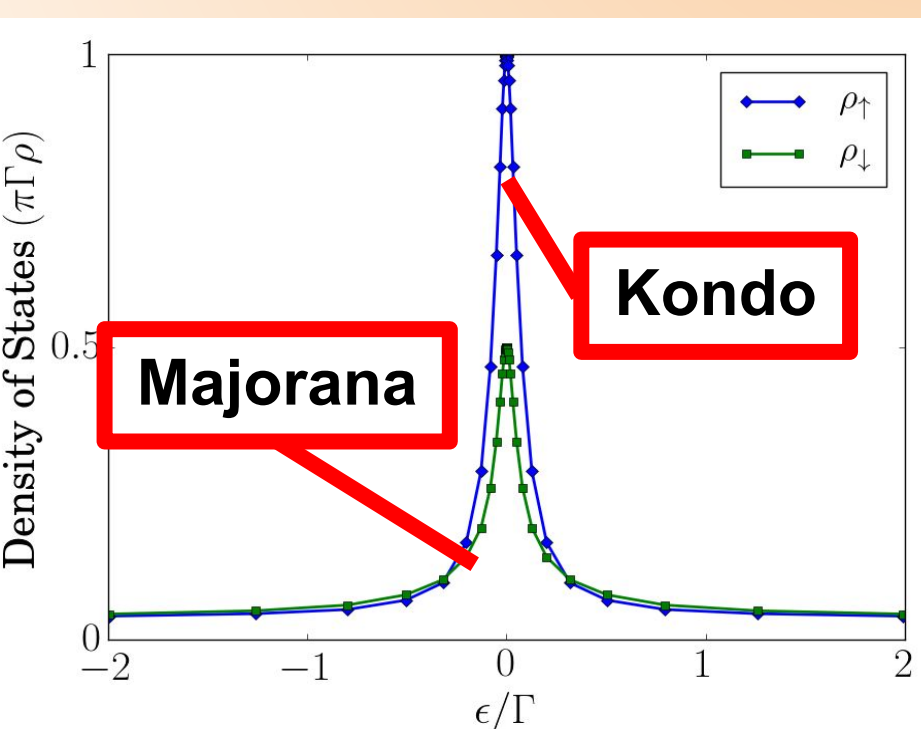


Motivation

When a QD is attached to a Majorana chain the Majorana mode localized at the edge of the chain leaks inside the QD [1]. The majorana signature is a zero-mode with half of the density of states of the expected peak (Spin-up) [3]. Recent proposals use multidot systems to create topological quantum computers [4]. This process requires total control of the Majorana mode inside the QD. The simplest case where Majorana manipulation is feasible is in a Double Quantum Dot. The simplicity of this model favors the derivation of a complete analytical solutions using ballistic transport. NRG computations confirm the observed results in interacting systems.



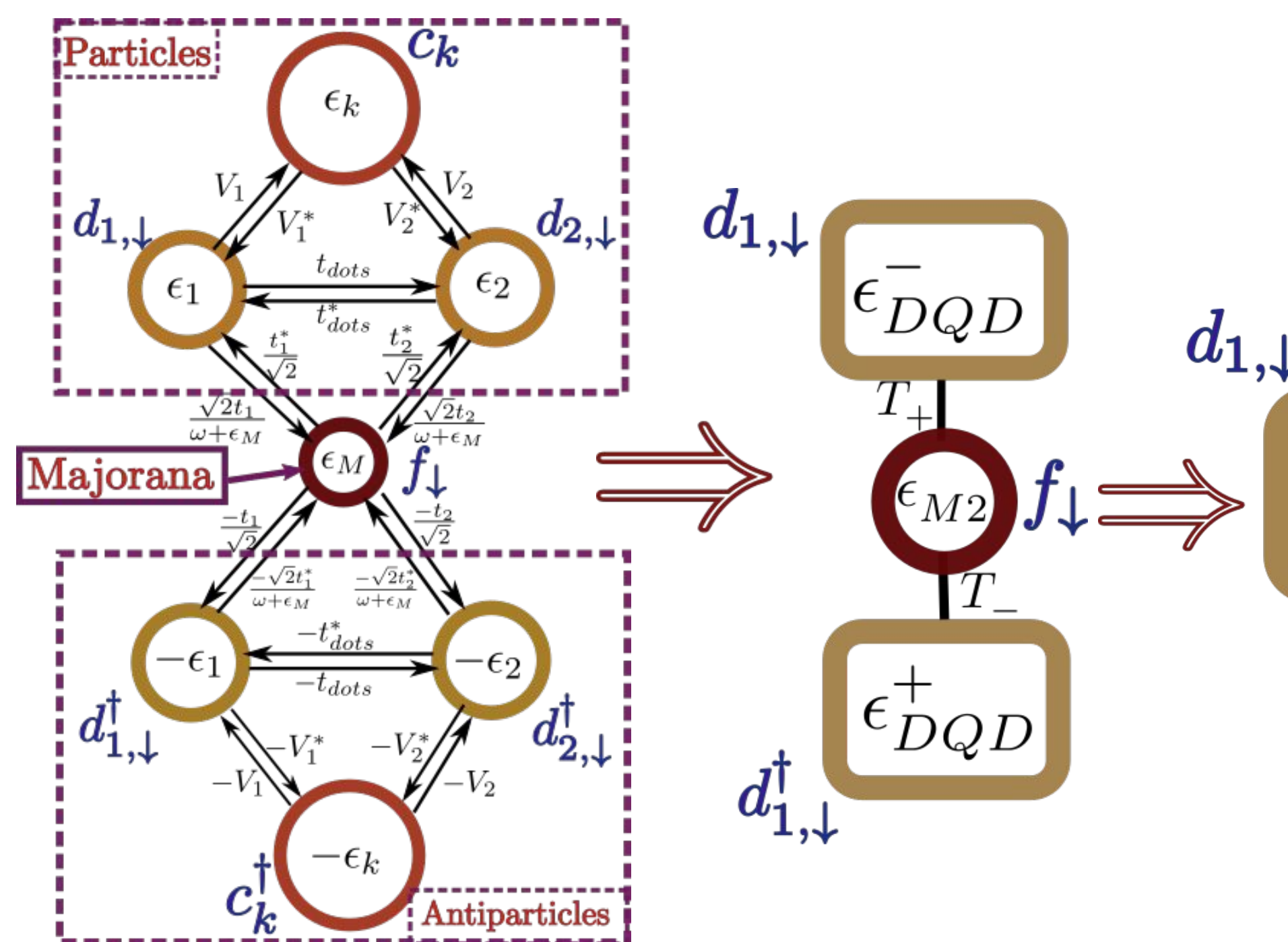
b) Experiment: Emergent QD at the end of a Majorana Chain. [2]



d) Base structure for a QD Majorana topological quantum computer. [4].

c) Majorana and Kondo peaks [3].

Non-interacting U=0 (Transport Flux)



Green Function:

$$G_{d_{1\downarrow}, d_{1\downarrow}^\dagger}(\omega) = \frac{1}{\omega - \epsilon_{DQD}^+ + \frac{\|T_+\|^2}{\omega - \epsilon_{M2} - \frac{\|T_-\|^2}{\epsilon_{DQD}^-}}}$$

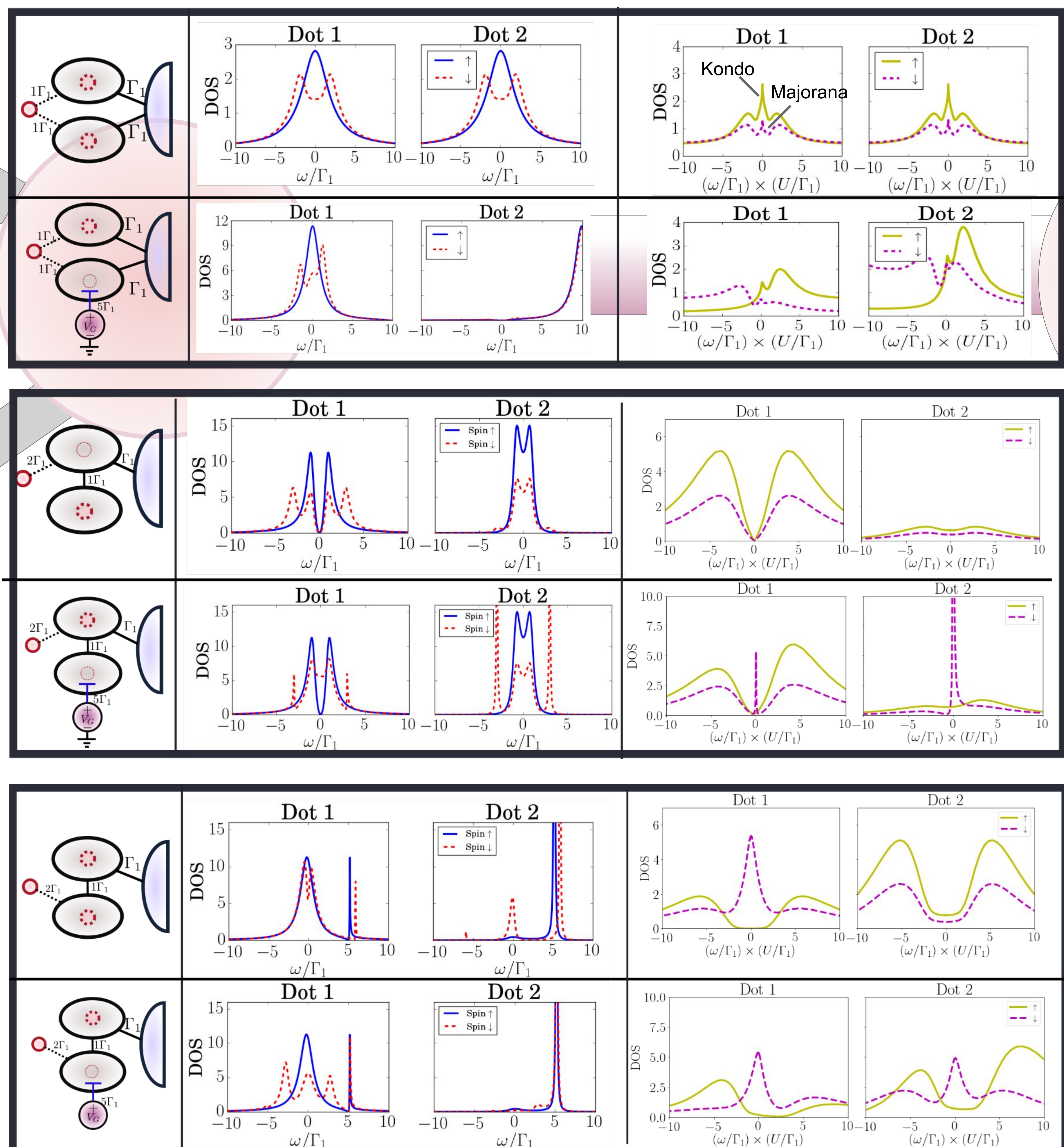
Density of States (DOS):

$$\rho_1(\omega) = -\frac{1}{\pi} \text{Im} \left[G_{d_{1\downarrow}, d_{1\downarrow}^\dagger}(\omega) \right]$$

Setup

Non-Interacting U=0

Interacting Case U>0 (NRG)



Conclusions & Future Work

- If there is a symmetric coupling between the Majorana and both quantum dots, the majorana signature appears in both dots.
- The indirect coupling of the second QD can destroy the majorana signature by quantum interference. Indirect majorana signatures can also appear .
- The majorana can be induced to

“leave” one dot by increasing the gate voltage of it.

- In the interacting case, the observed majorana signatures confirm the non-interacting results. Kondo and Majorana signatures can coexist.

References

- [1] Liu, D. E. & Baranger, H. U. Physical Review B 84, (2011).
- [2] Deng MT, Vaitiekėnas S., et al. Science.354 (6319):1557–6
- [3] Ruiz-Tijerina, D. A., et al. Phys. Rev. B 91, 115435 (2015).
- [4] Karzig, T. et al. Phys. Rev. B 95, 235305 (2017).

Possible Setups

