Manipulation of Majorana Modes in Double Quantum Dots

Jesús David Cifuentes†, Luis Dias da Silva

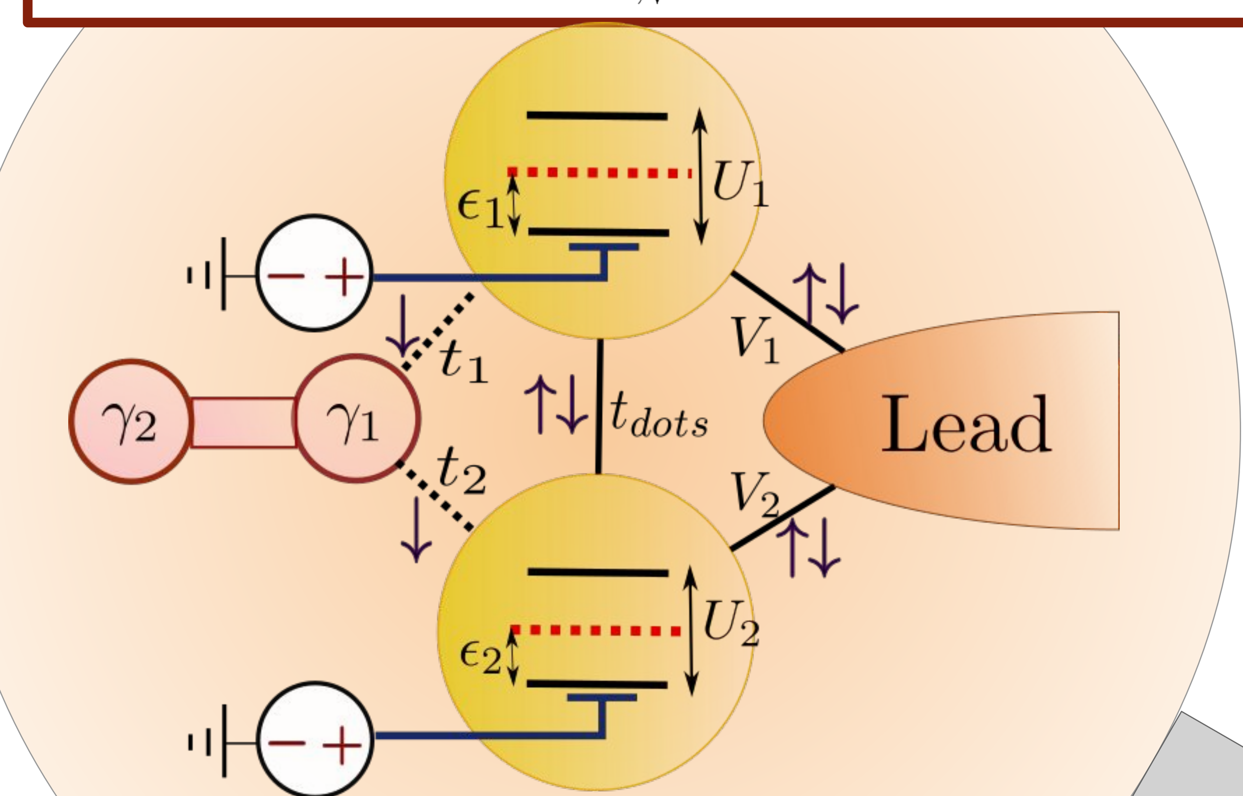
Instituto de Física, Universidade de São Paulo

jesuscif@if.usp.br

Model

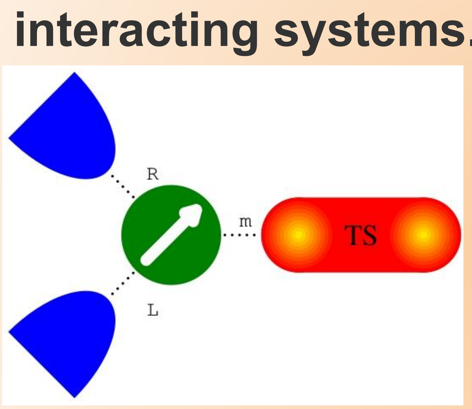
We study the electronic tranport in a Double Quantum Dot (DQD) coupled to metallic leads and to a Majorana chain.

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

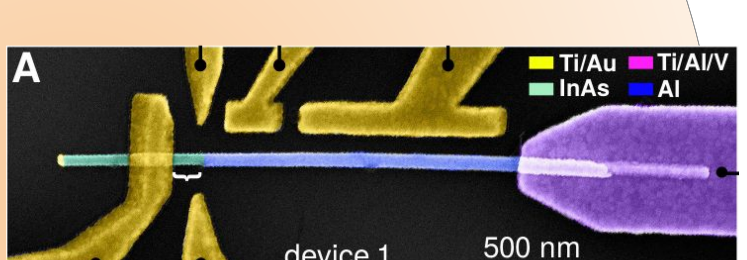


Motivation

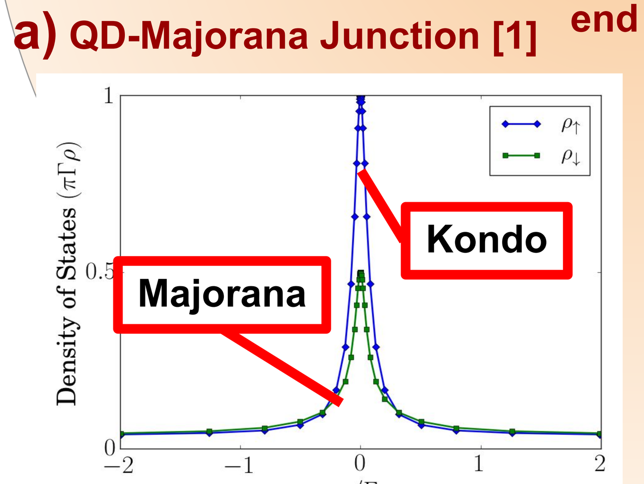
When a QD is attached to a Majorana chain the Majorana mode localized at the edge of the chain leaks inside the QD [1]. The majorana signature is a zero-mode with half of the density of states of the expected peak (Spin-up) [3]. Recent proposals use multidot systems to create topological quantum computers [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.



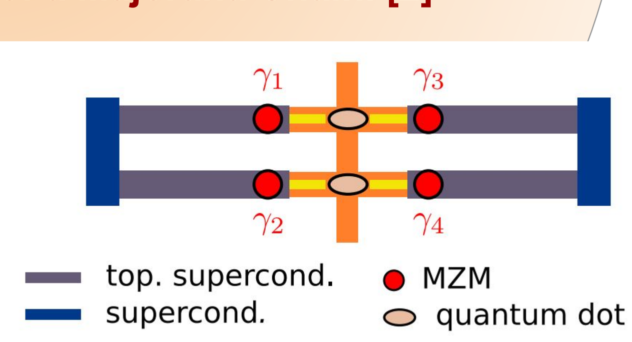
a) QD-Majorana Junction [1]



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

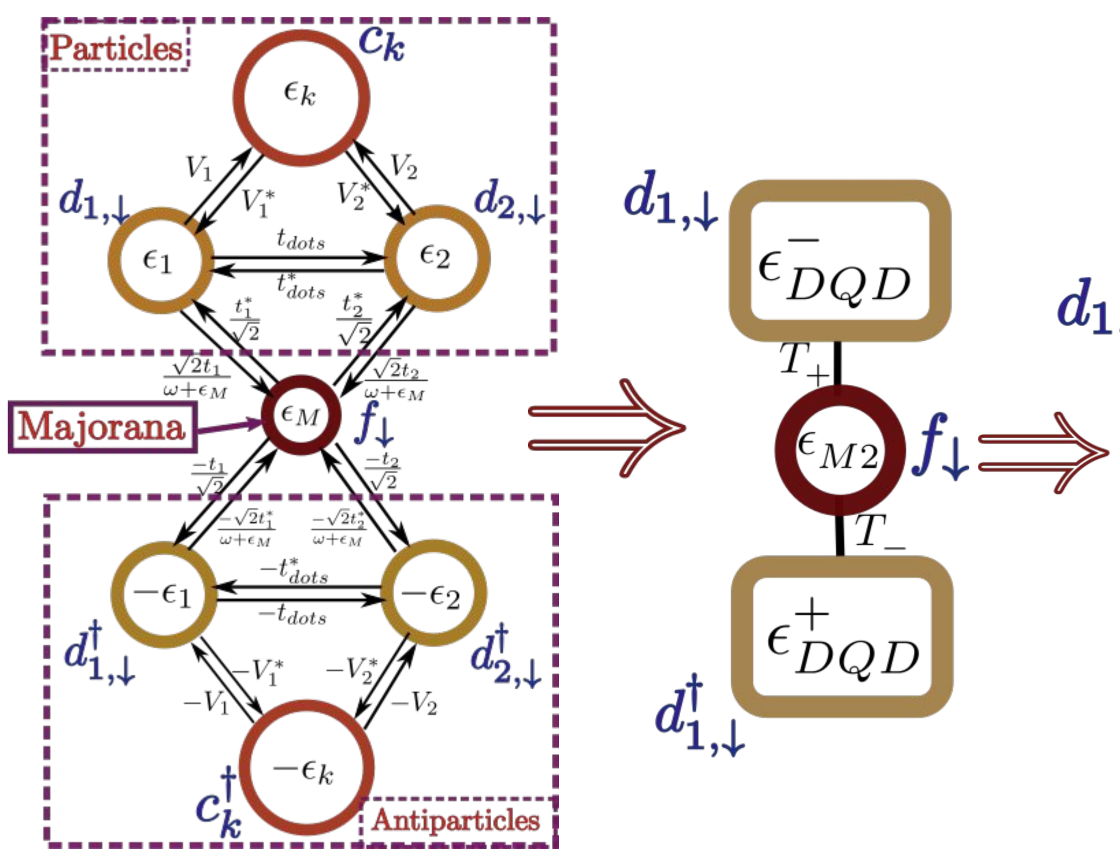


c) Majorana and Kondo peaks [3].



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

Non-interacting U=0 (Transport Flux)



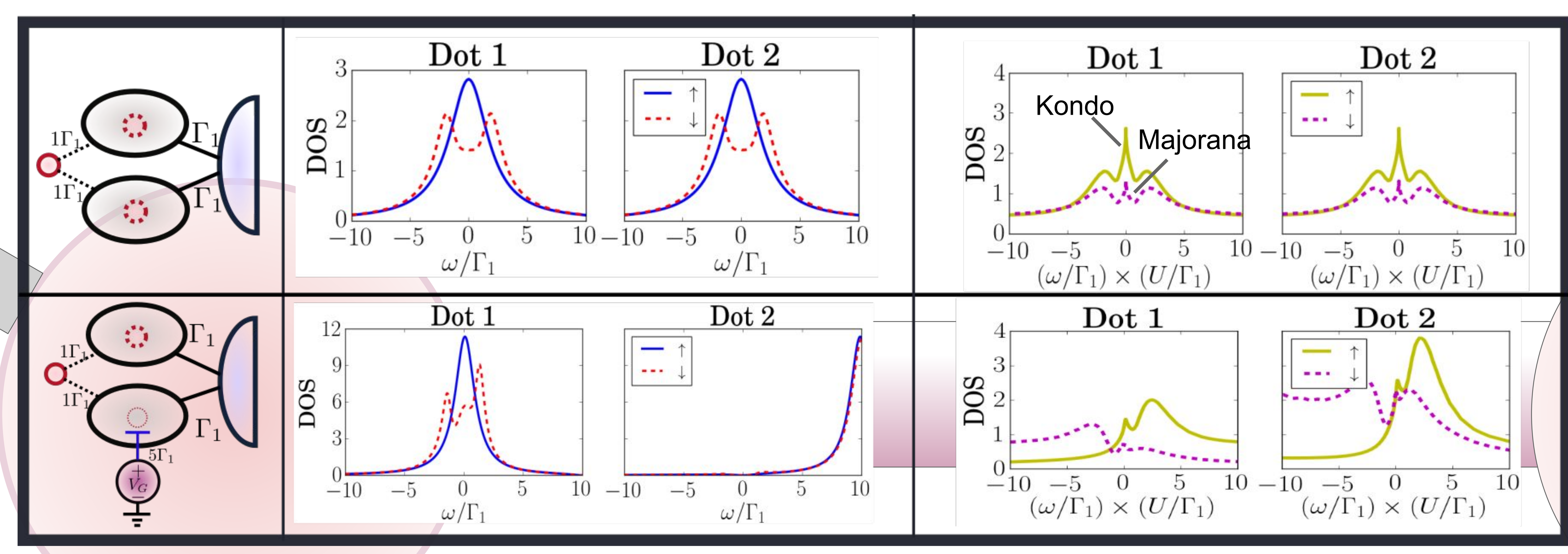
Green Function:

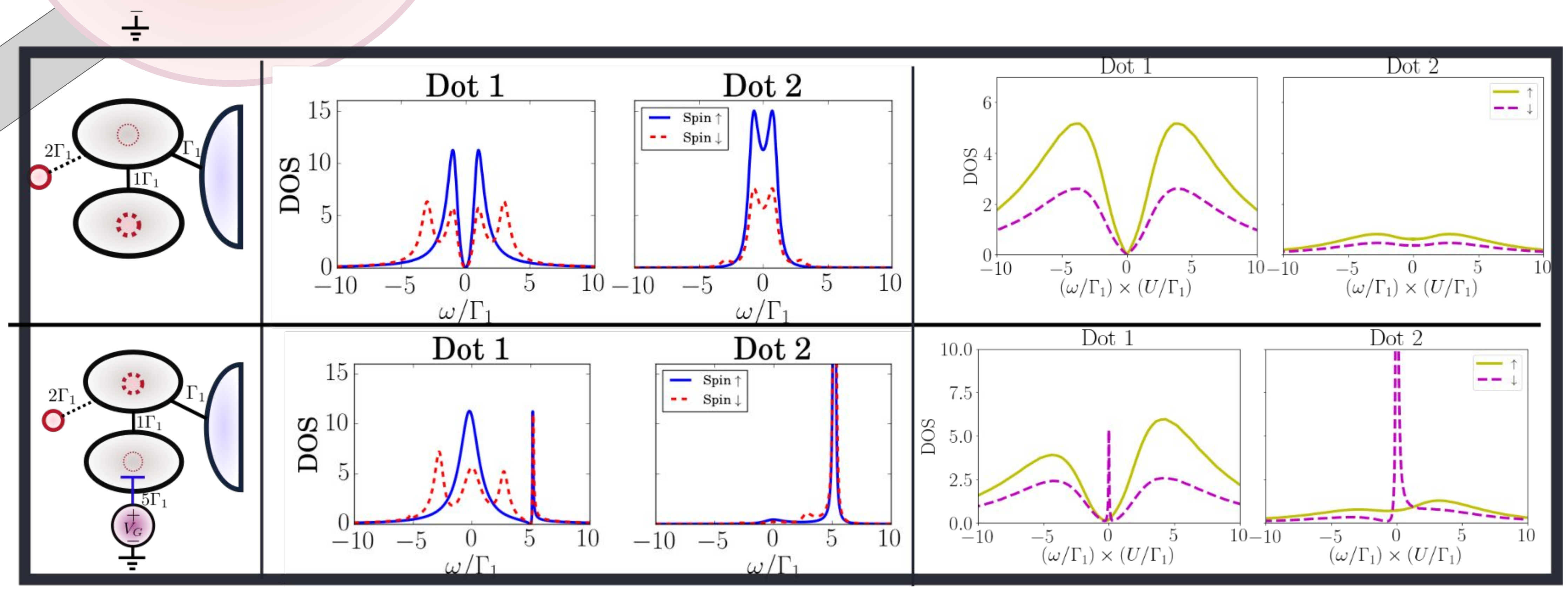
$$G_{d_{1\downarrow},d^\dagger_{1\downarrow}}(\omega)=\frac{1}{\omega-\epsilon^+_{DQD}+\frac{\|T_+\|^2}{\omega-\epsilon_{M2}-\frac{\|T_-\|^2}{\epsilon^-_{DQD}}}}$$

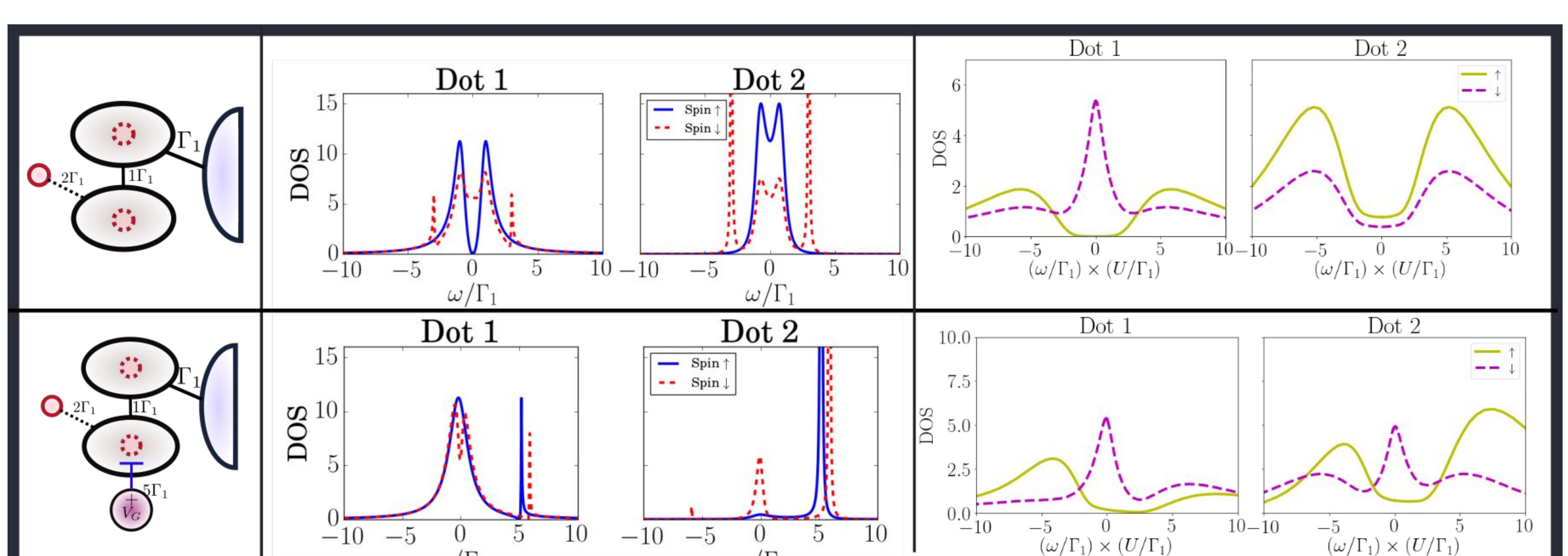
Density of States (DOS):

$$\rho_1(\omega)=-\frac{1}{\pi}\mathrm{Im}\left[G_{d_1,d_1^\dagger}(\omega)\right]$$

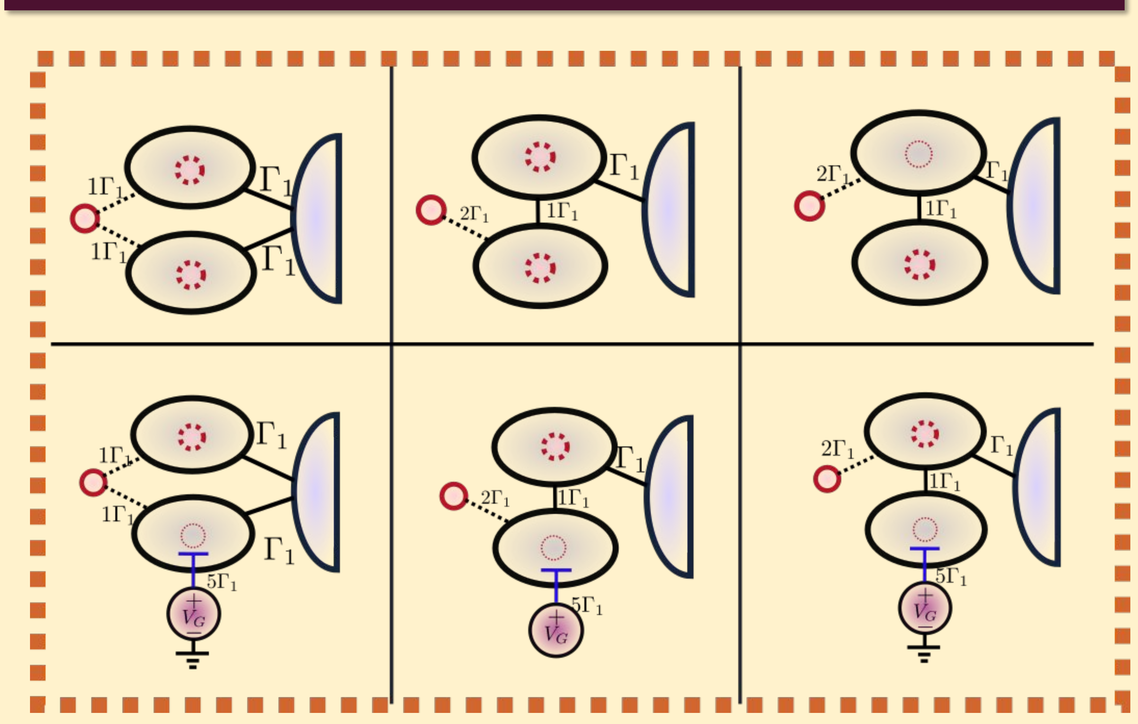
Setup | Non-Interacting U=0 | Interacting Case U>0 (NRG)







Possible Setups



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).

INSTITUTO DE FÍSICA