Seeing the strongly-correlated zero-bias anomaly in double quantum dot measurements

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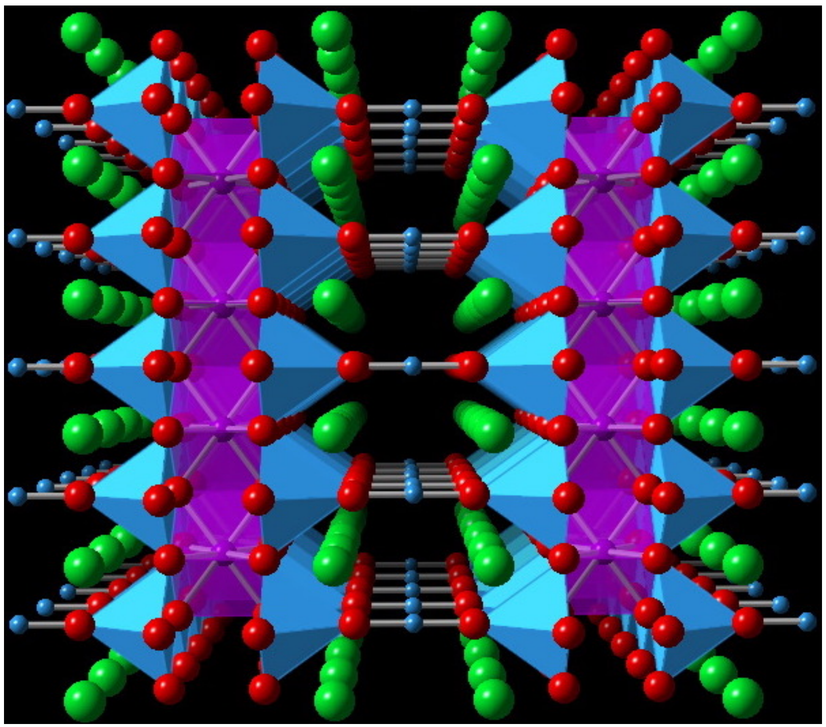
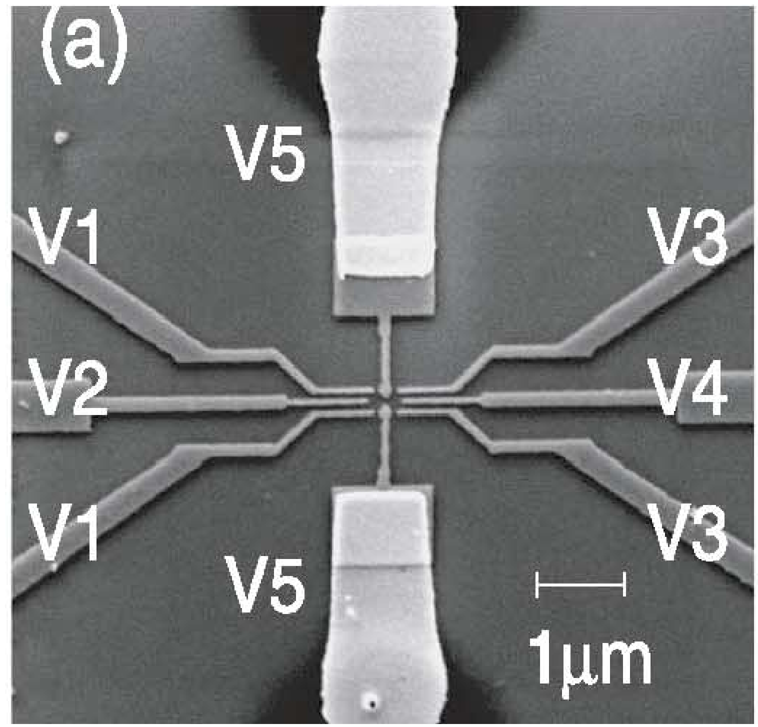
Connecting

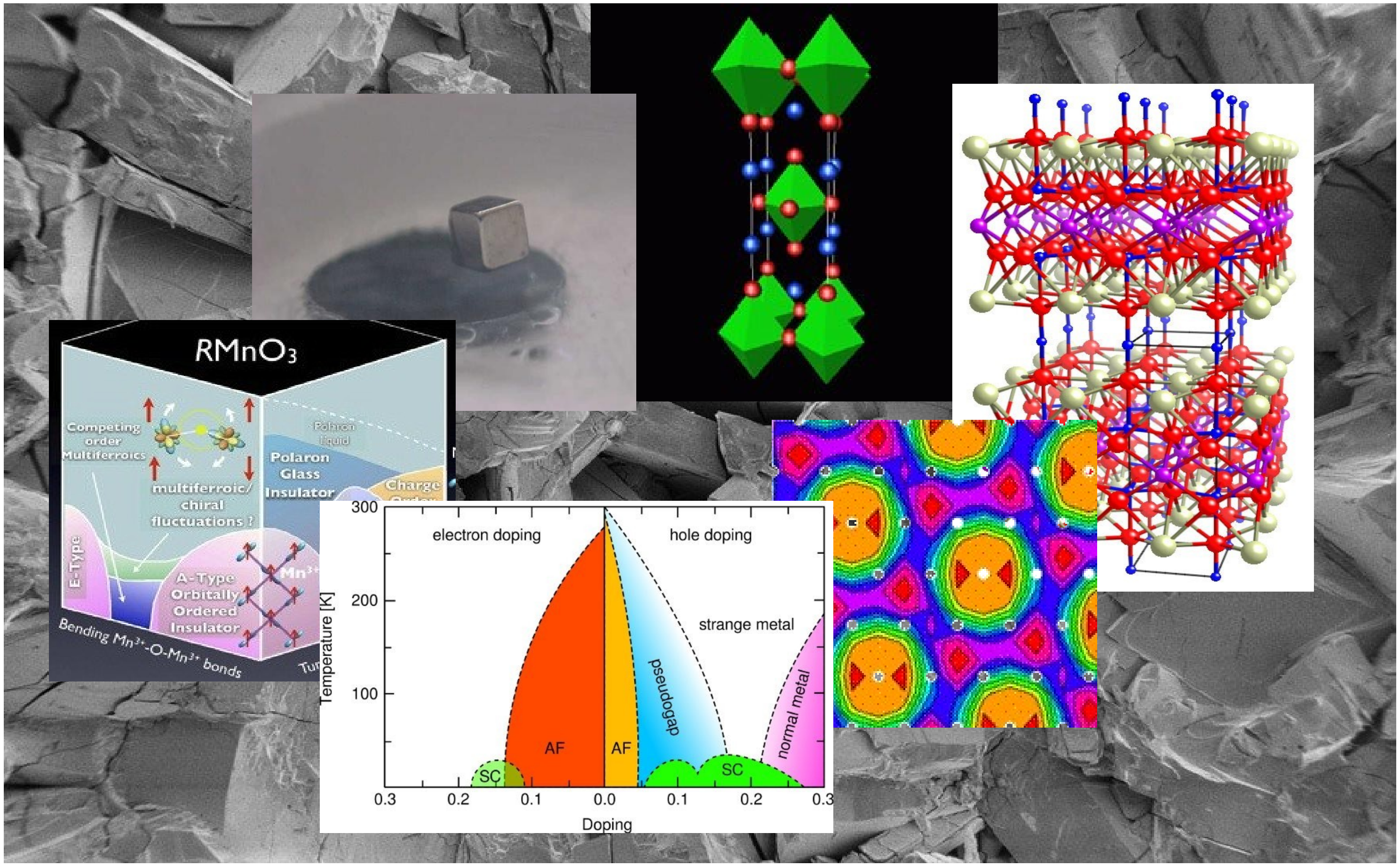
bulk strongly-correlated materials



double quantum dots



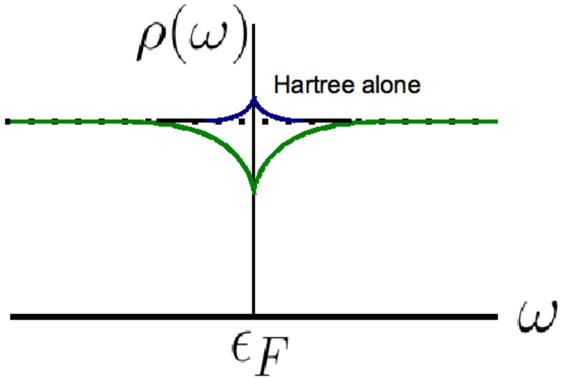
Transition metal oxides



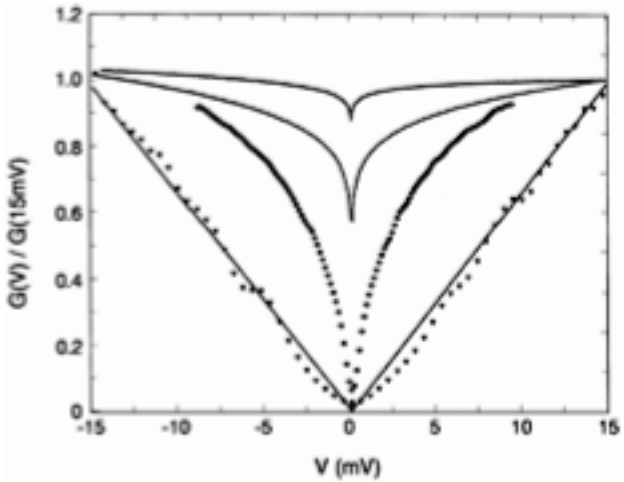
What does disorder do to strongly correlated systems?

What do interactions do to disordered systems?

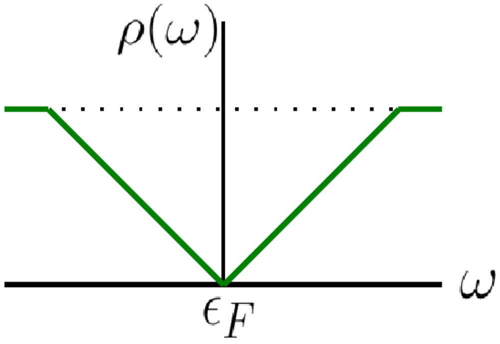
Zero-bias anomalies



Altshuler-Aronov
weak interactions & disorder

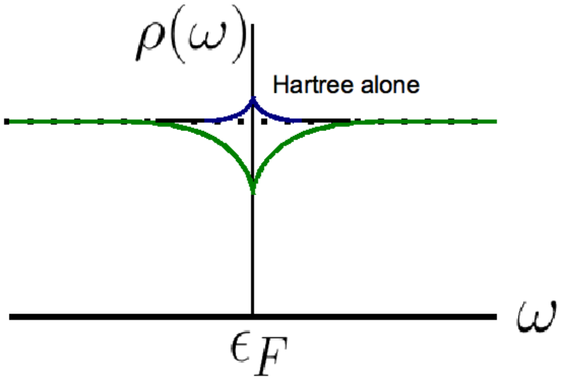


Butko, *et al*, PRL 2000



Efros-Shklovskii
atomic limit, 1/r Coulomb

Zero-bias anomalies



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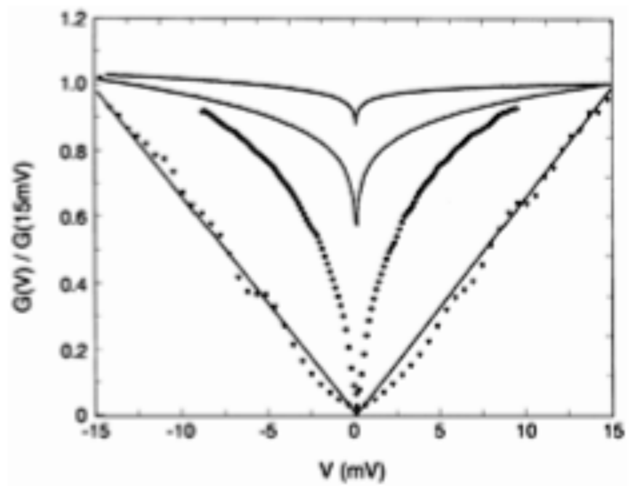

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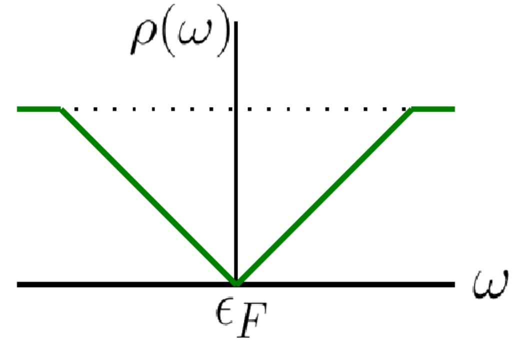

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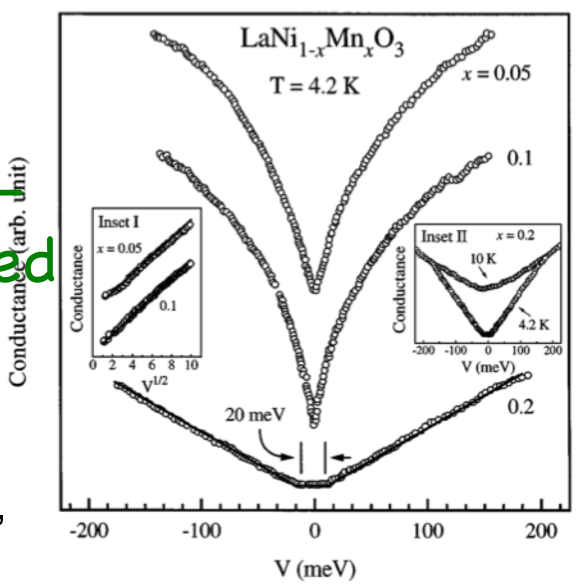
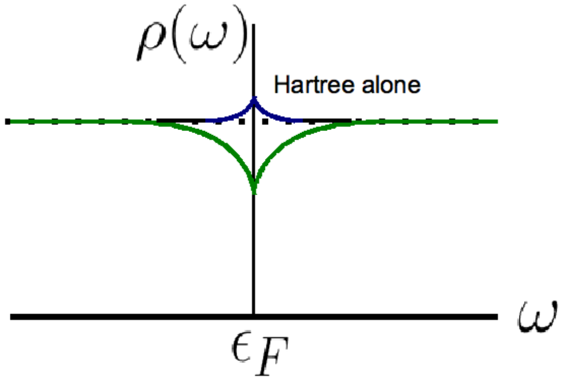
atomic limit, 1/r Coulomb

strongly-correlated expt



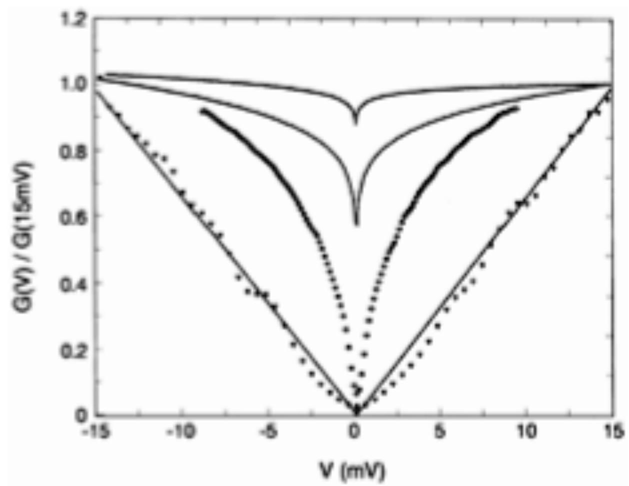
Sarma, *et al*,
PRL 1998

Zero-bias anomalies



Altshuler-Aronov

weak interactions & disorder



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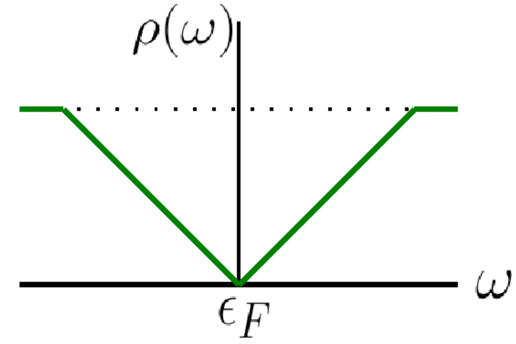

Efros-Shklovskii

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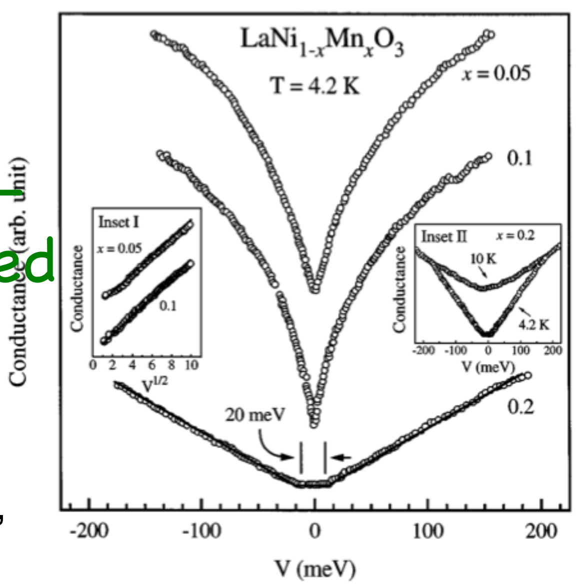

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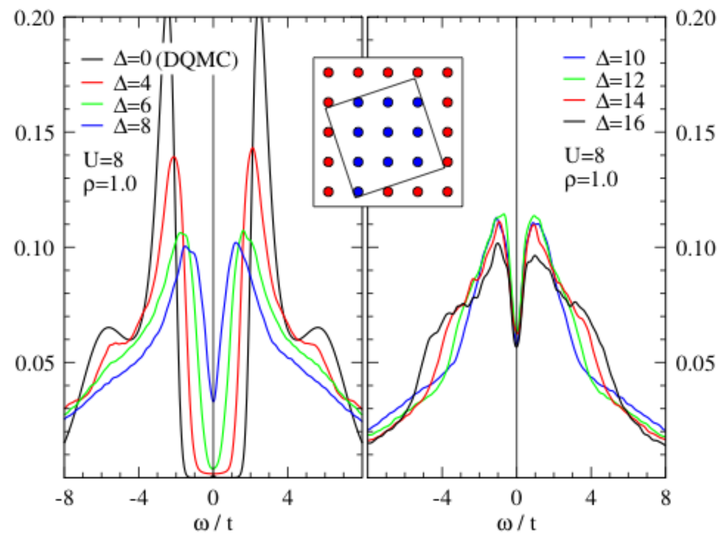


strongly-correlated theory

Chiesa, *et al*, PRL 2008

strongly correlated systems: kinetic-energy-driven zero bias anomaly

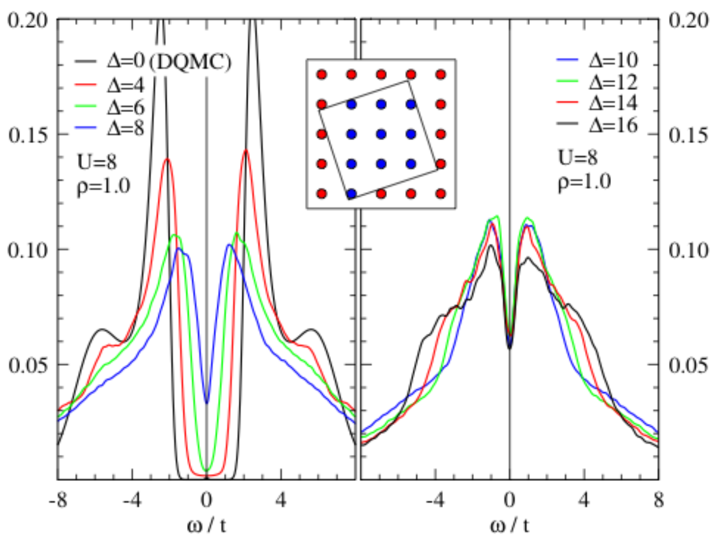
$$\mathcal{H} = -t \sum_{\langle ij \rangle,\sigma} c_{i\sigma}^{\dagger} c_{j\sigma} + U \sum_{i} n_{i\uparrow} n_{i\downarrow} + \sum_{i,\sigma} \epsilon_i n_{i\sigma}$$

ZBA

independent of

- interaction strength
- disorder strength
- chemical potential

width linear in t



Chiesa, *et al*, PRL 2008

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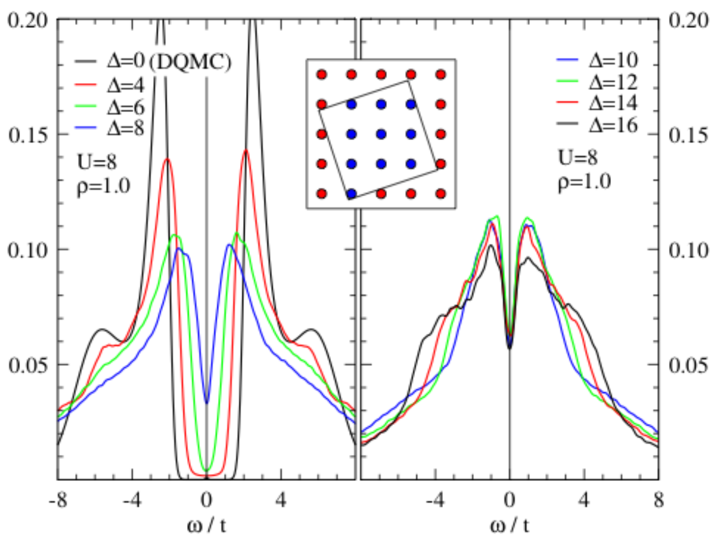
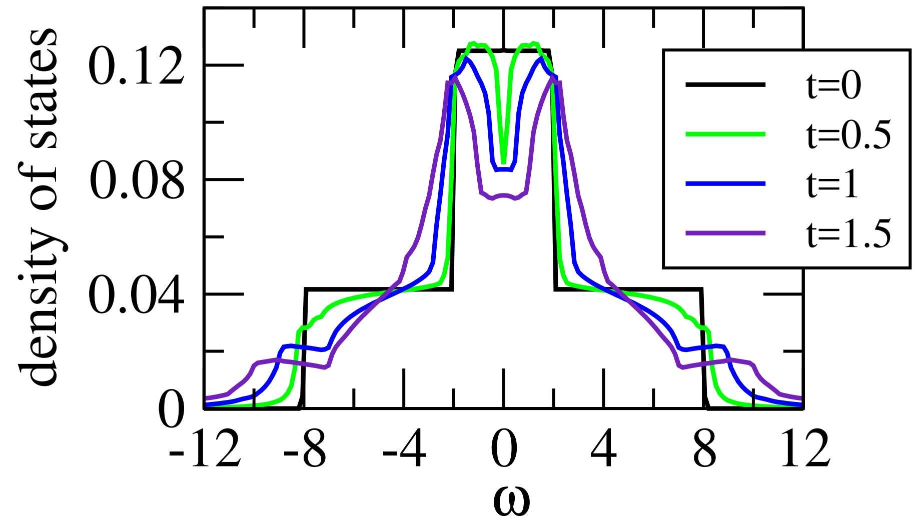


Chiesa, *et al*, PRL 2008



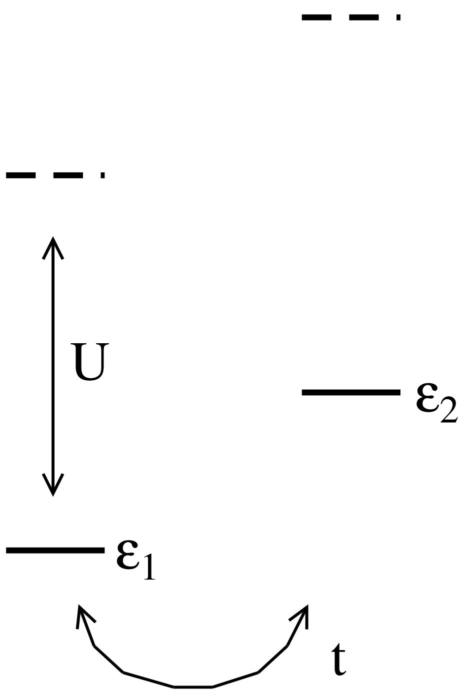
Wortis & Atkinson, PRB 2010

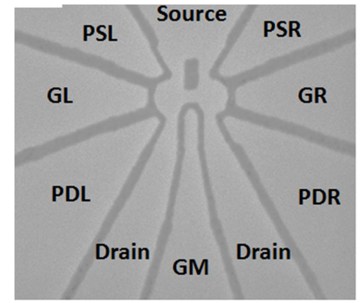
ensemble of two-site systems
-> ZBA with the same parameter dependence as the bulk crystal

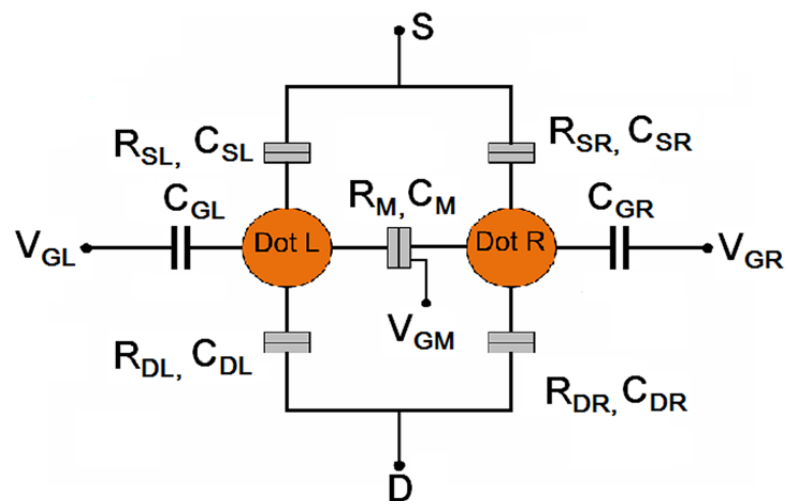
parallel-coupled double quantum dots

$$\mathcal{H} = -t \sum_{\langle ij \rangle, \sigma} c^{\dagger}_{i\sigma} c_{j\sigma} + U \sum_{i} n_{i\uparrow} n_{i\downarrow} + \sum_{i,\sigma} \epsilon_i n_{i\sigma}$$

Wang, *et al*, APL 2011



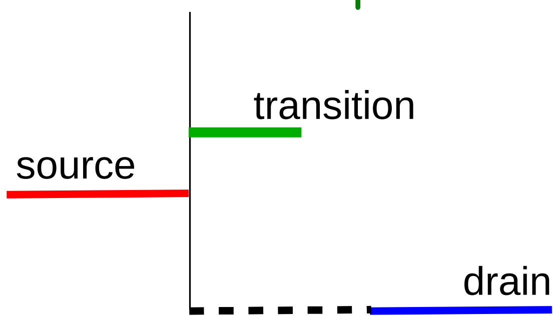


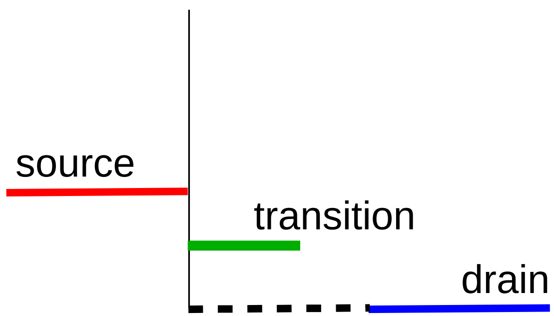


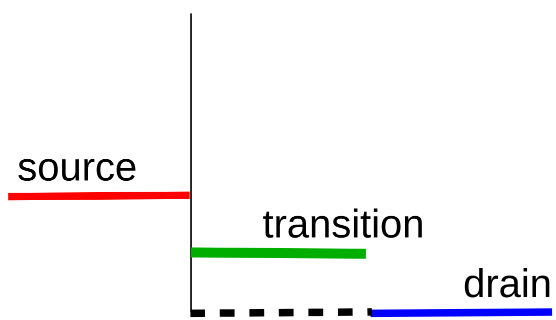
parallel-coupled double quantum dots

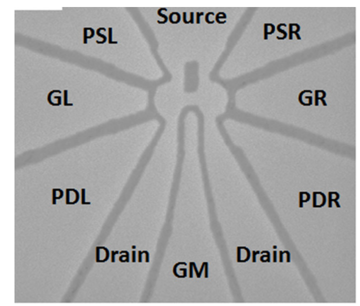
lower drain barrier -> focus on transitions which add one particle to the ground state

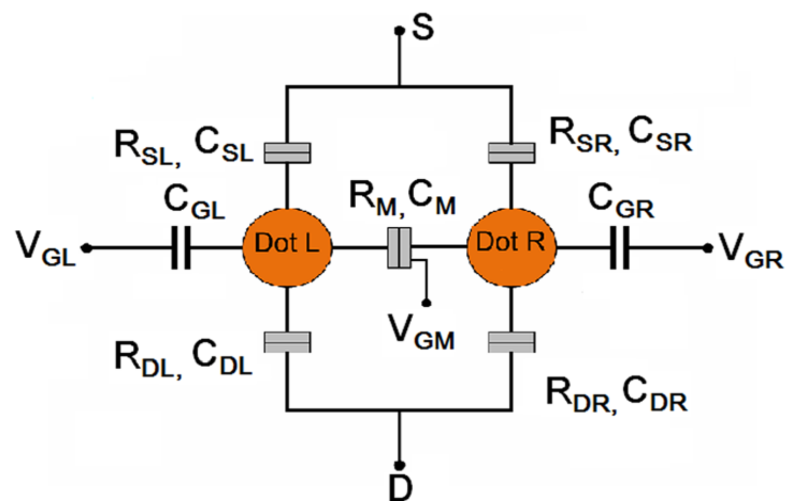
Wang, *et al*, APL 2011



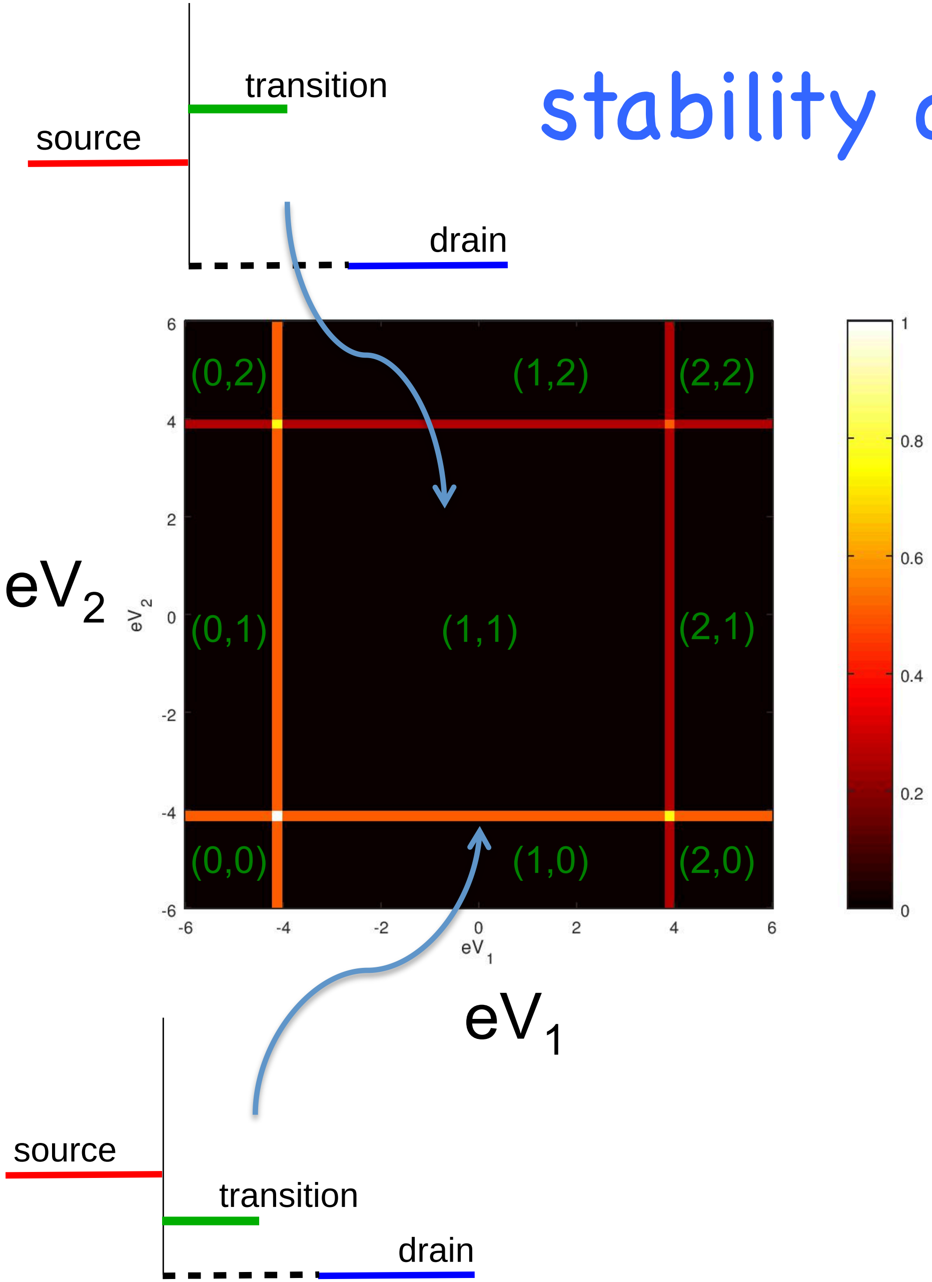








stability diagrams



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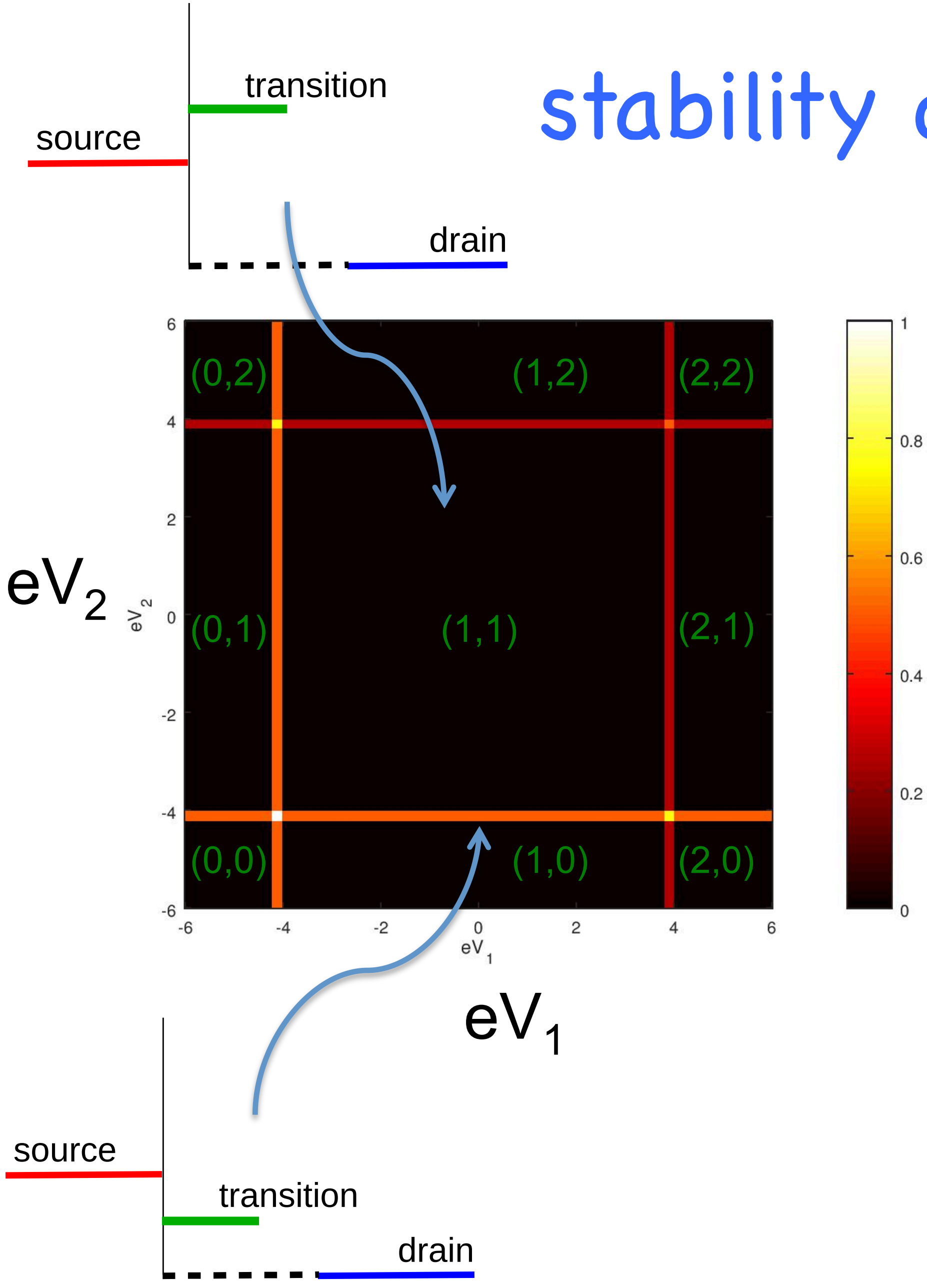
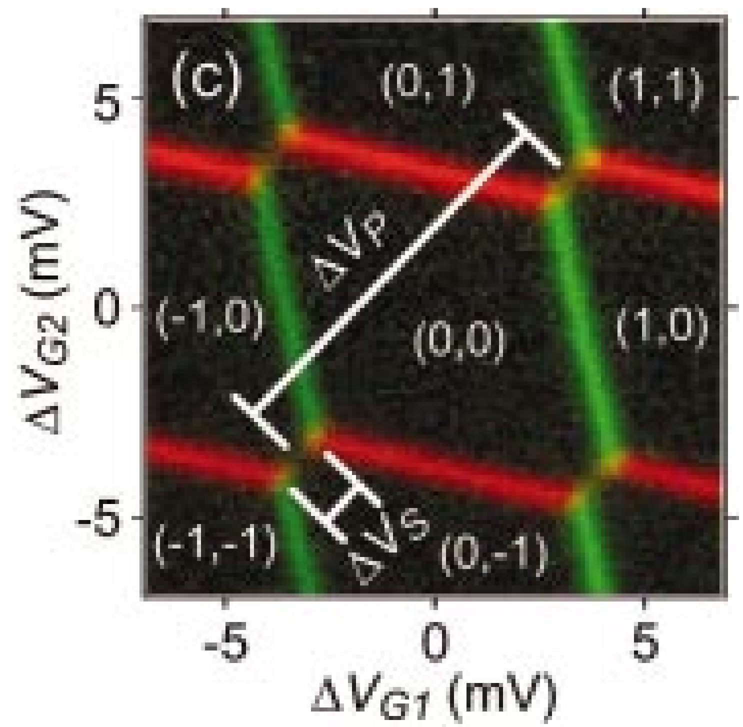
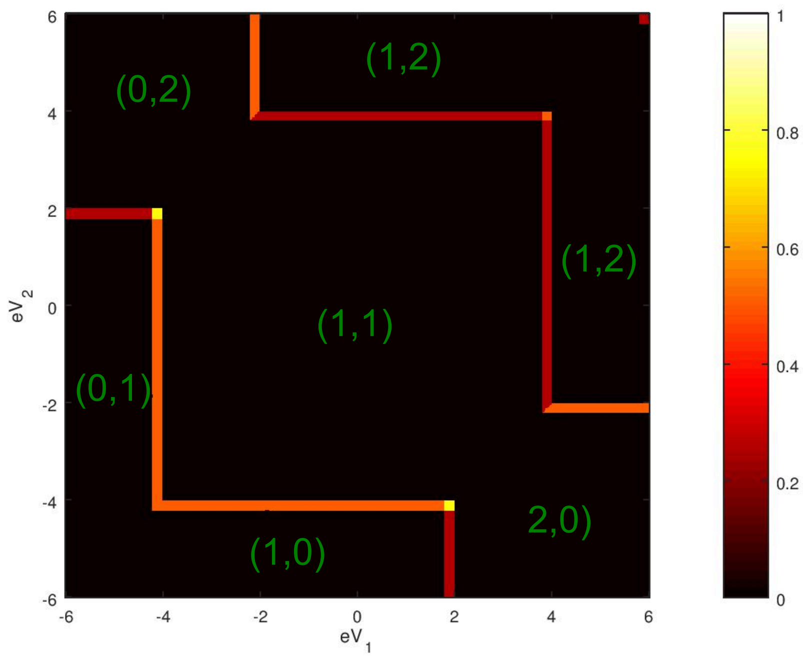




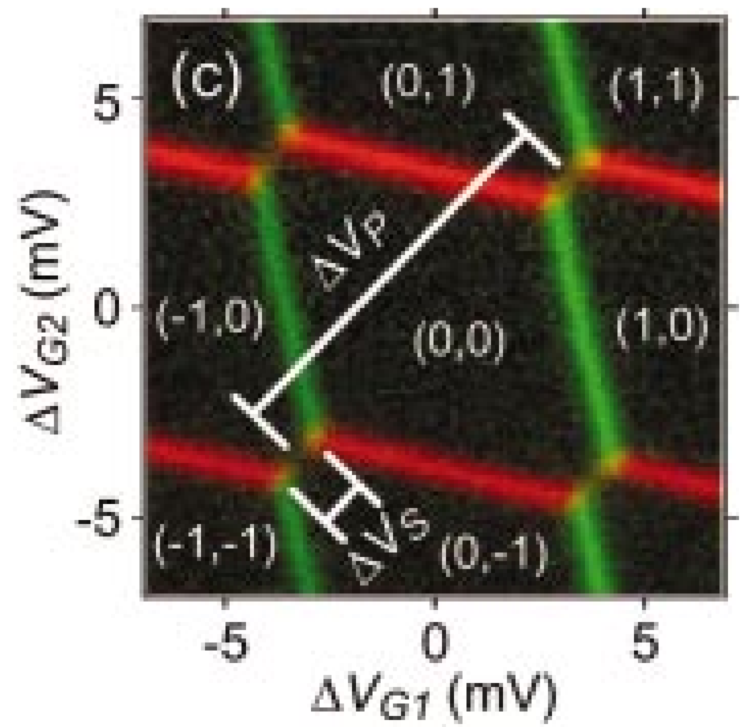
Chan, *et al*, APL 2002

stability diagrams

eV_2



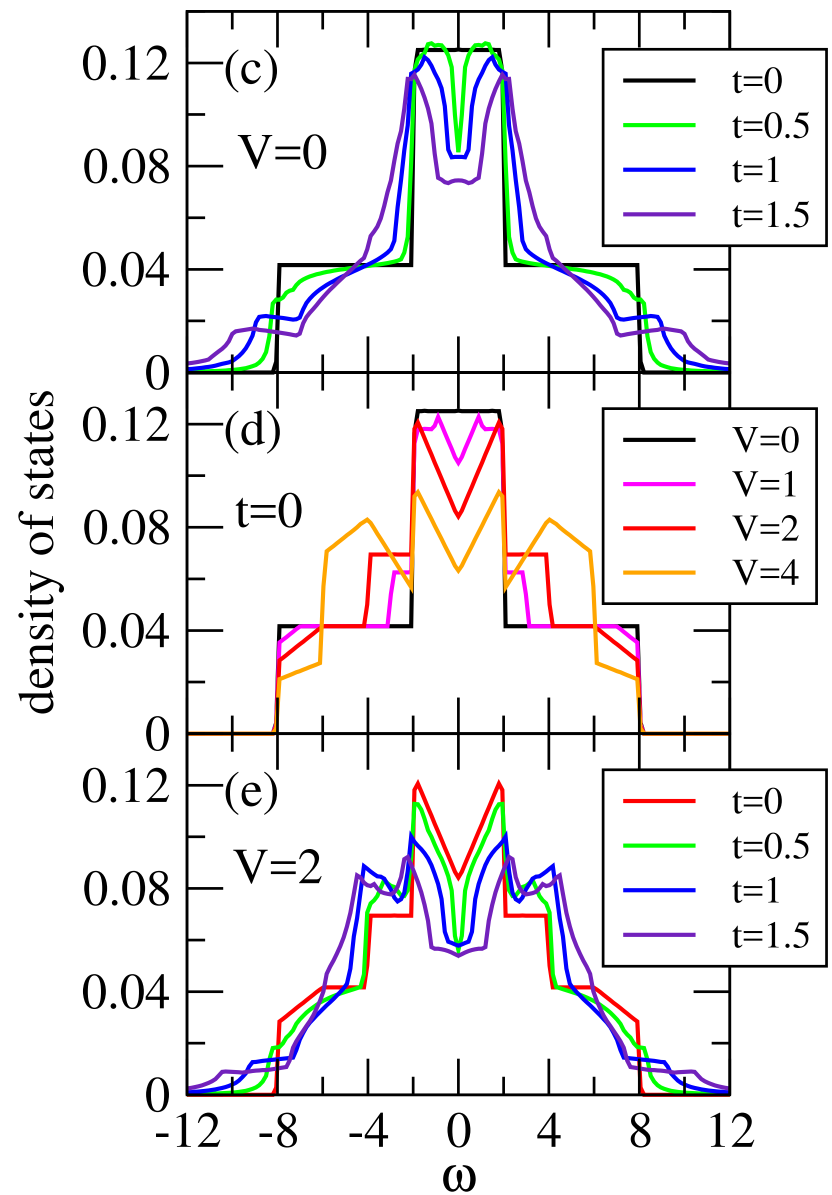
eV_1



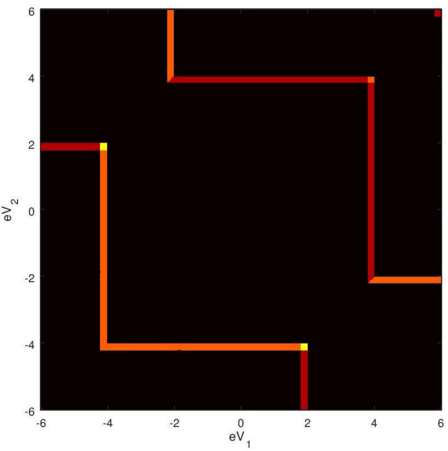
Chan, *et al*, APL 2002

including nearest-neighbor interactions

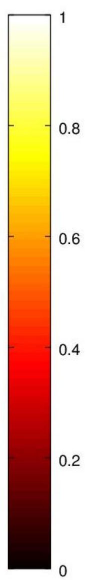
$$\mathcal{H} = -t \sum_{\langle ij \rangle,\sigma} c_{i\sigma}^\dagger c_{j\sigma} + U \sum_i n_{i\uparrow} n_{i\downarrow} + \sum_{i,\sigma} \epsilon_i n_{i\sigma} + \boxed{V \sum_{\langle ij \rangle} n_i n_j}$$

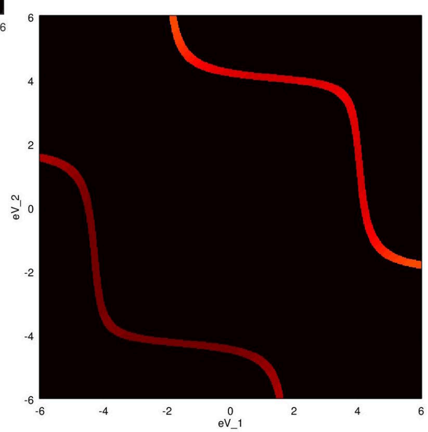


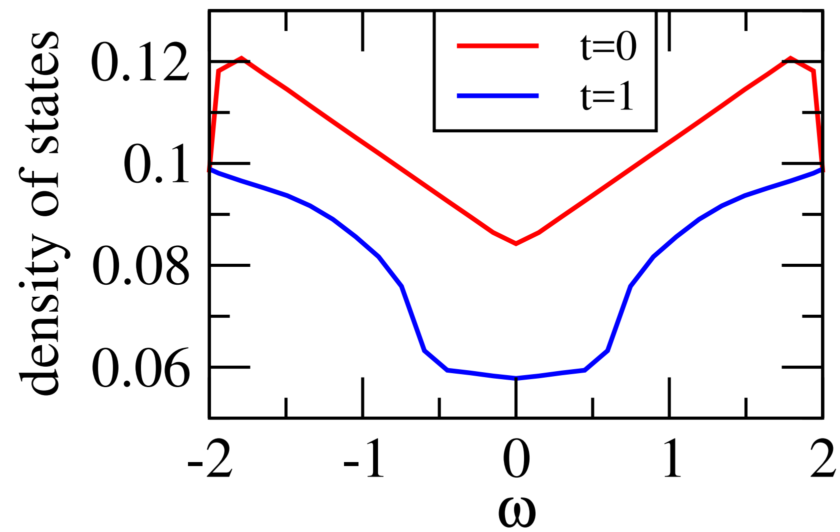
seeing the zero bias anomaly in stability diagrams



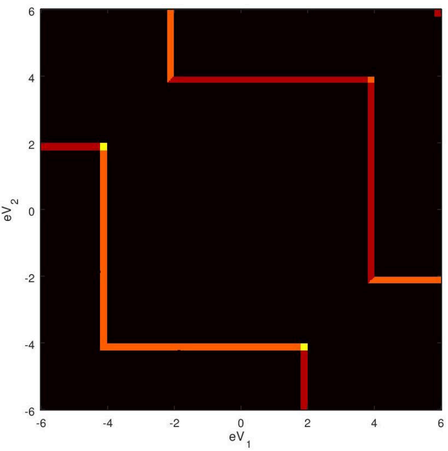
lower barrier
(increase hopping)







seeing the zero bias anomaly in stability diagrams



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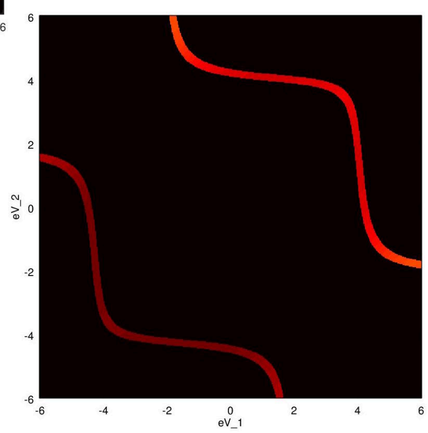
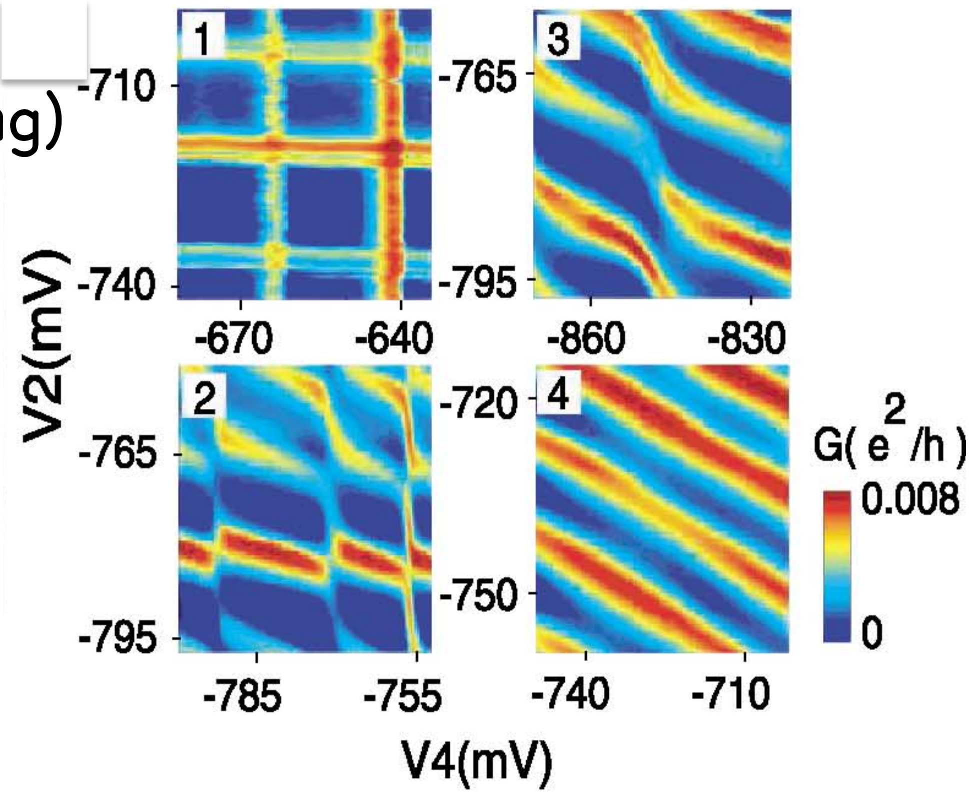


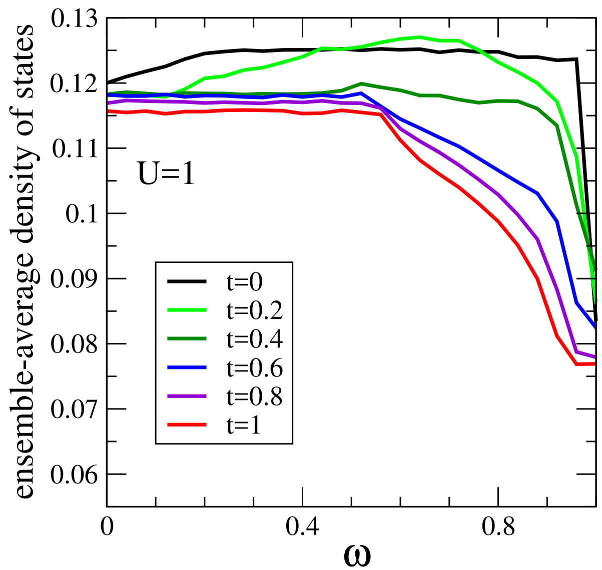


Chen, *et al*, PRL 2004

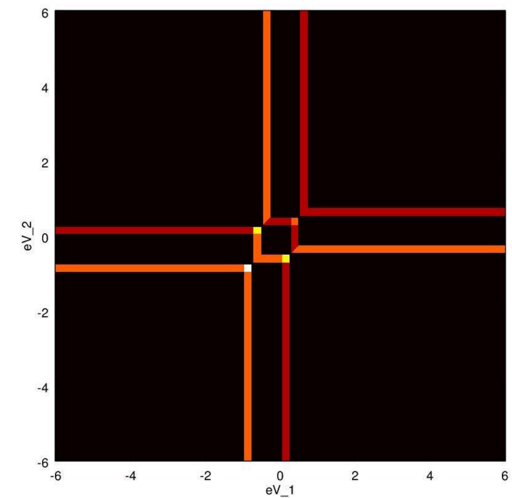
shows suppression of density of states at zero bias
BUT does not distinguish between different mechanisms

seeing the energy dependence of the zero bias anomaly

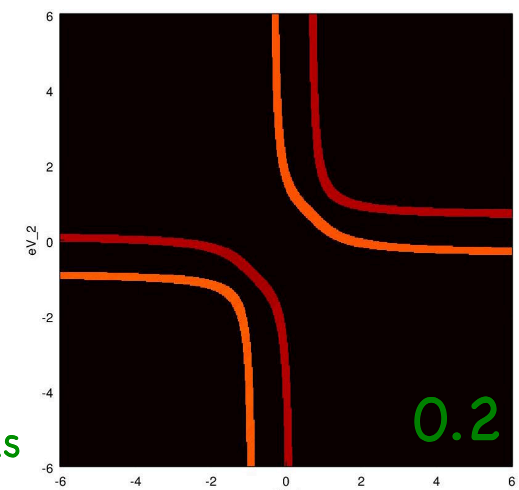
U=1



t=0



t=0.6



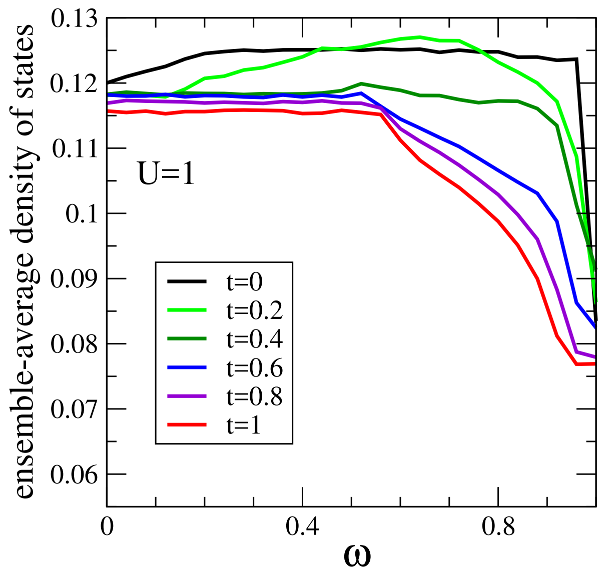
V_{bias} 0.2

seeing the energy dependence of the zero bias anomaly

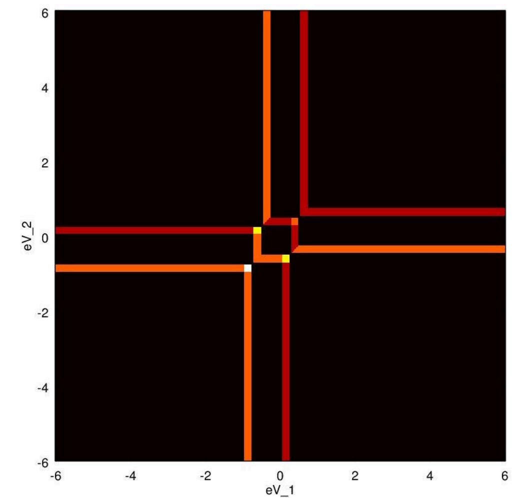
U=1

no zero-bias anomaly

little V_{bias} dependence

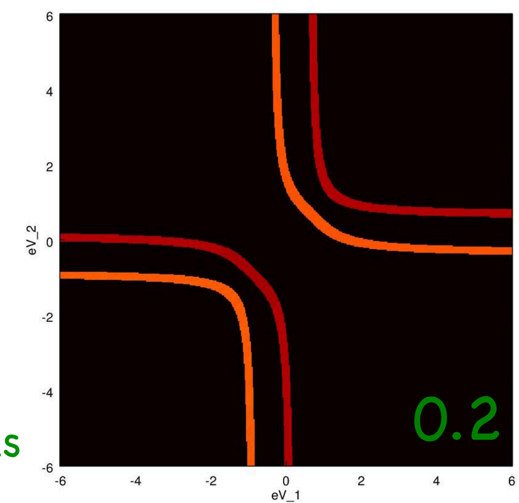


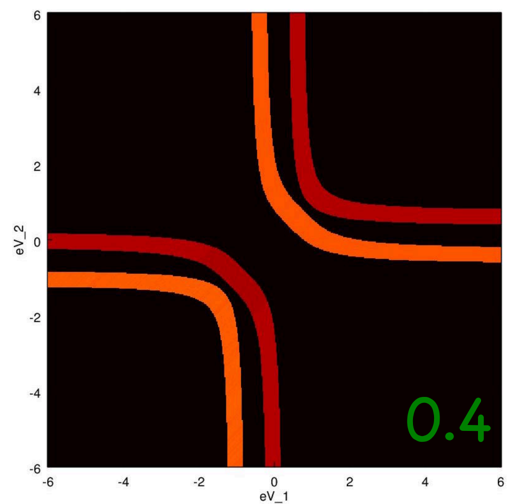
t=0

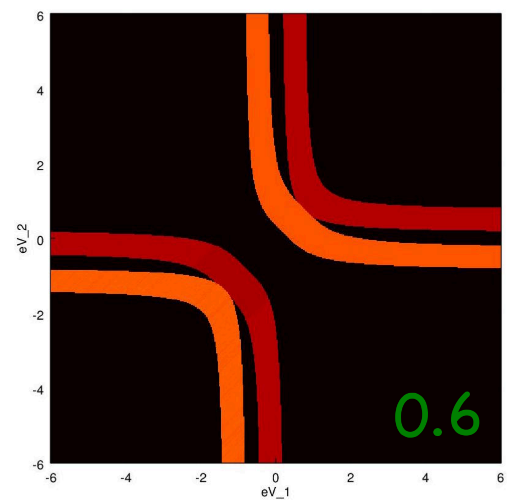


t=0.6

V_{bias}

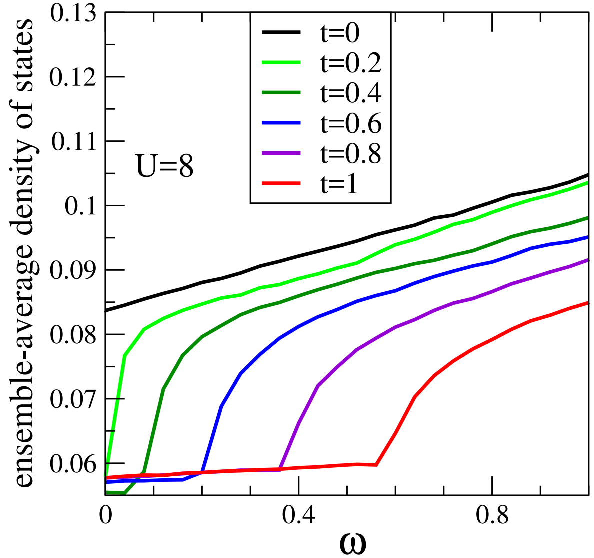




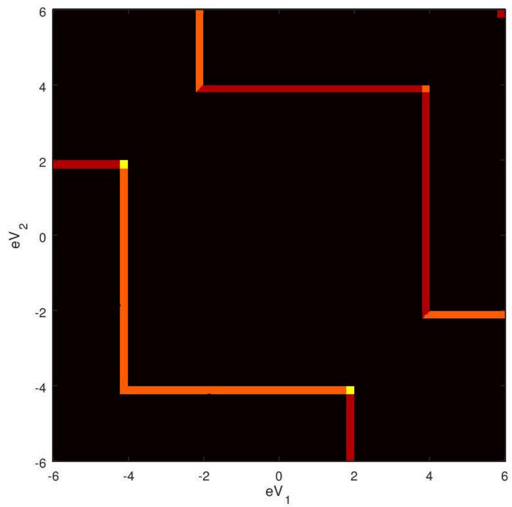


seeing the energy dependence of the zero bias anomaly

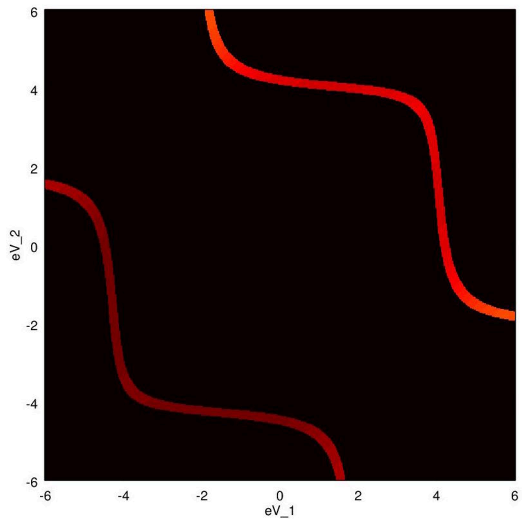
U=8



t=0



t=0.6



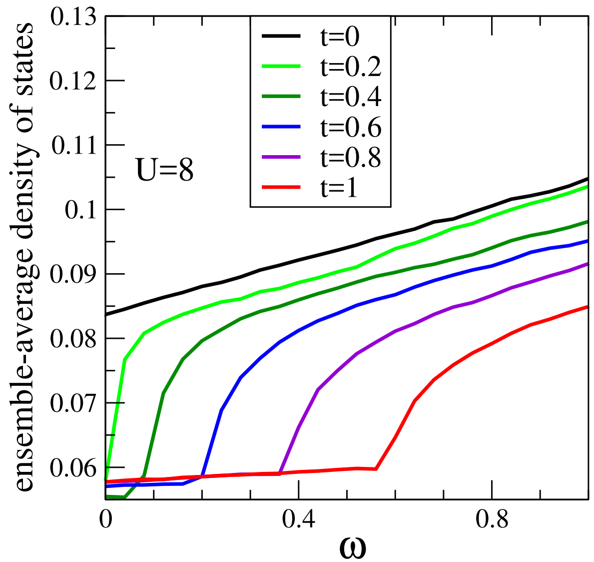
V_{bias}

seeing the energy dependence of the zero bias anomaly

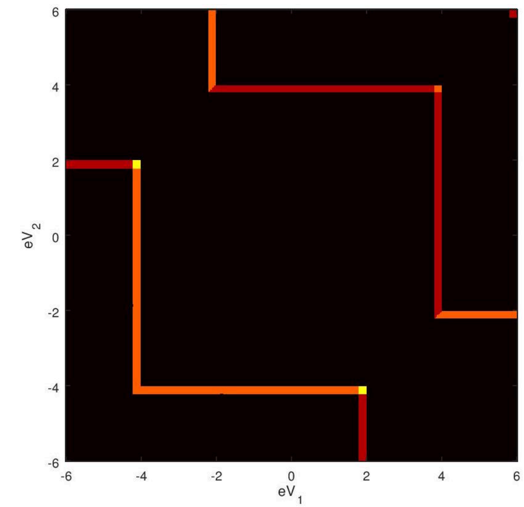
U=8

zero-bias anomaly

strong V_{bias} dependence

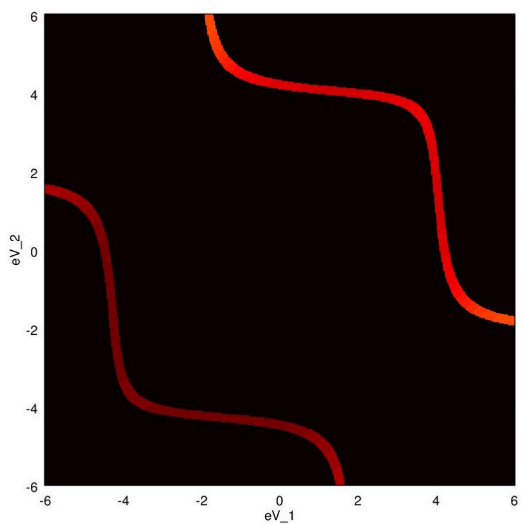


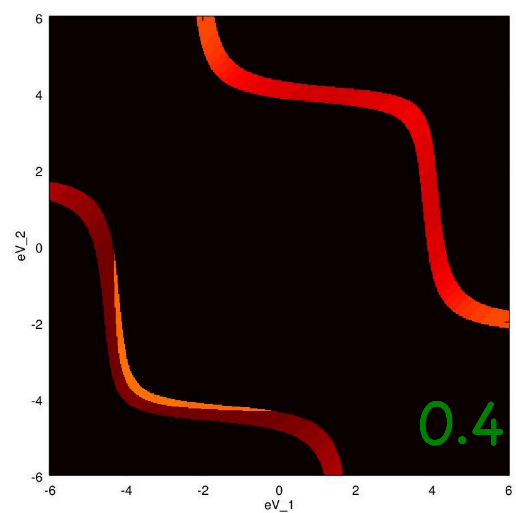
t=0

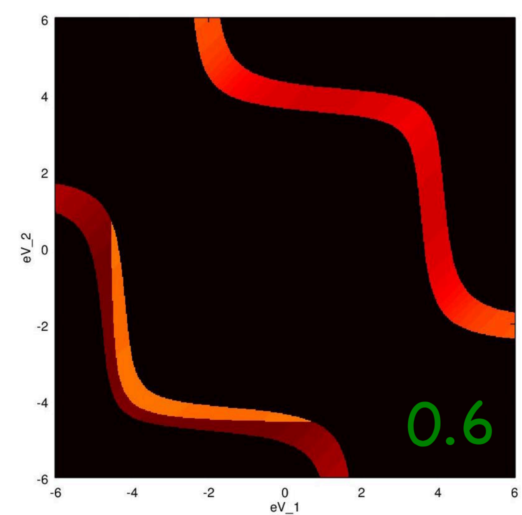


t=0.6

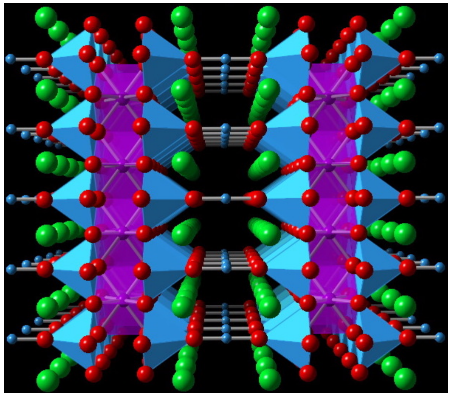
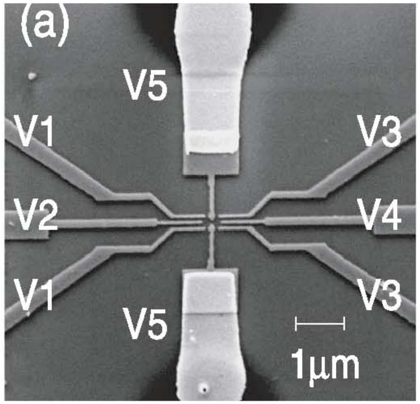
V_{bias}







Summary

Connecting  and 

Using DQDs to see the physics of the zero-bias anomaly in bulk disordered strongly-correlated materials

- simple: less ensemble-averaged current at zero bias when the tunnel barrier is lowered

- better: use differential conductance as a function of V_{bias} to distinguish the kinetic-energy-driven effect, a unique signature of strong correlations