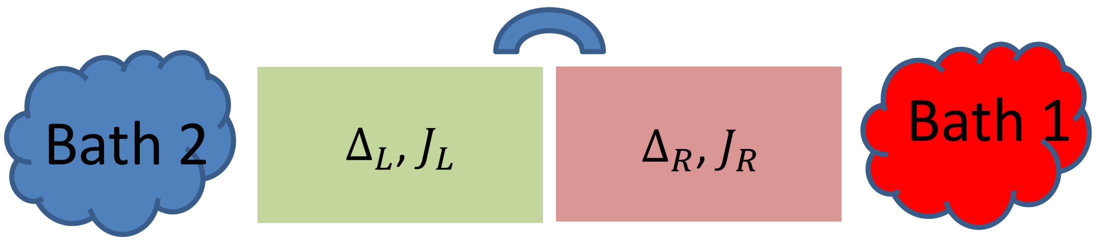
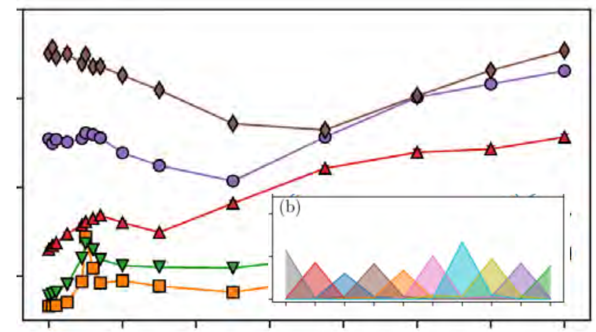
Many-body open quantum systems: transport and localization





SPICE – Quantum thermodynamics and transport 2018
Mainz

Dario Poletti

Singapore University of Technology and Design
Majulab

SUTD-MIT INTERNATIONAL DESIGN CENTRE (IDC)

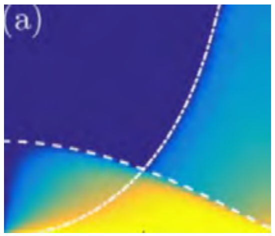
Ministry of Education SINGAPORE

V. Balachandran et al., Phys. Rev. Lett. (2018)
X. Xu et al., Phys. Rev. B 97, 140201(R) (2018)

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

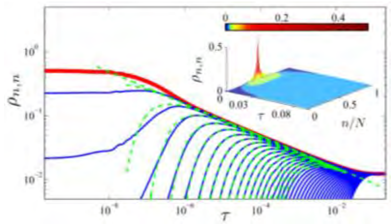
Manybody Open Quantum Systems

Out-of-Equilibrium Phase Transitions



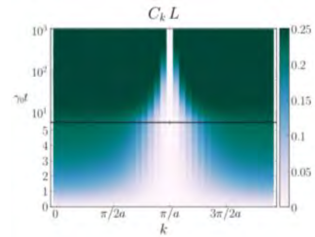
C. Guo D.P. PRA (2016)

Probing Systems



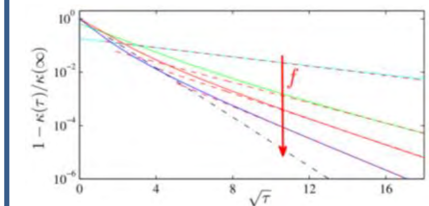
D.P. et al PRL (2012)

Generating Correlations



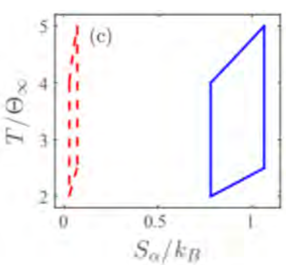
J.-S. Bernier et al. PRA (2013)

Relaxation Regimes



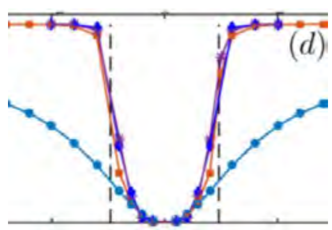
B.Sciolla. et al PRL (2015)

Energy Conversion



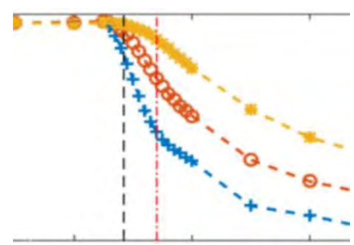
Y. Zheng, D.P., PRE (2015)

Transport



V. Balachandran, et al.
PRL (2018)

Stability

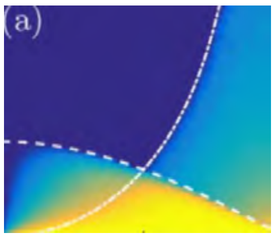


C. Guo et al. PRA (2018)

Matrix product state algorithm

Manybody Open Quantum Systems

Out-of-Equilibrium Phase Transitions



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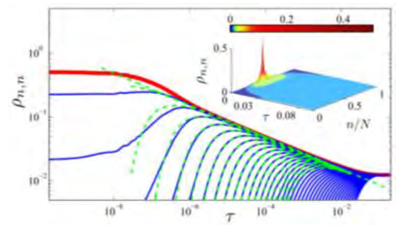
Probing Systems



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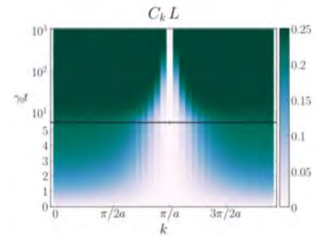

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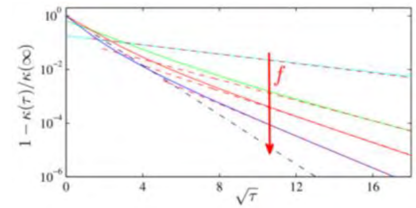

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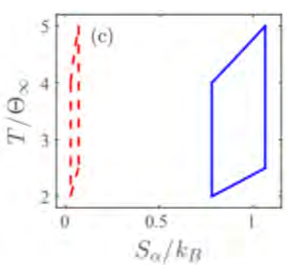

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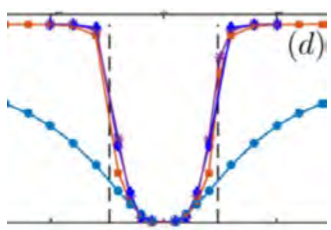

V. Balachandran, et al.
PRL (2018)

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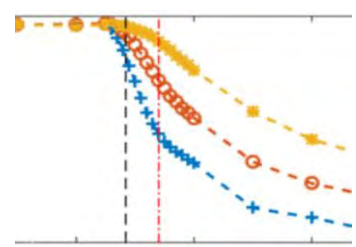
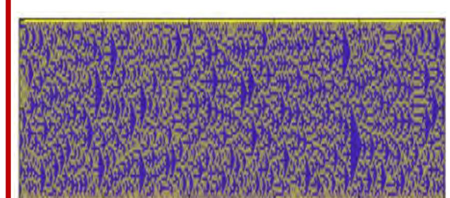


C. Guo et al. PRA (2018)

Machine Learning



C. Guo et al. (2018)

Matrix product state algorithm

Plan of the presentation

1) Perfect spin rectifier

Physical Review Letters (2018)

V. Balachandran

E. Pereira

G. Benenti

G. Casati

+ D.P.

2) Interplay between disorder, strong interactions and tailored dissipation

Physical Review B, 97, 140201(R) (2018)

X. Xu

C. Guo

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Conclusions and Outlook

Plan of the presentation

1) Perfect spin rectifier

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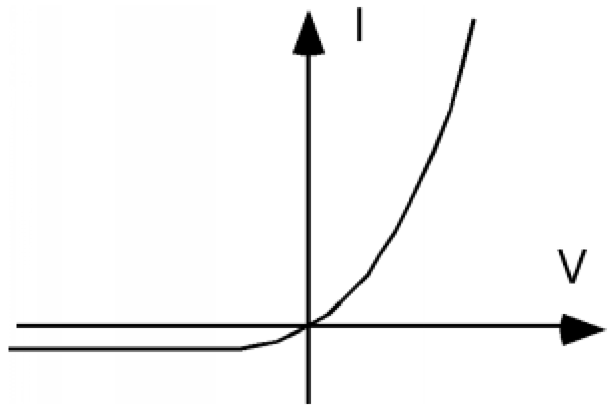
+ D.P.

X. Xu C. Guo

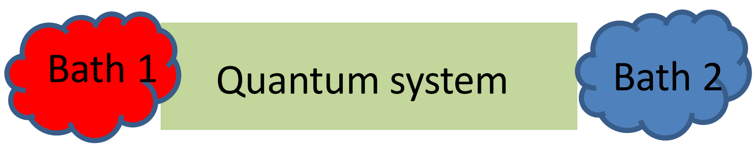
Conclusions and Outlook

Perfect spin current rectifier

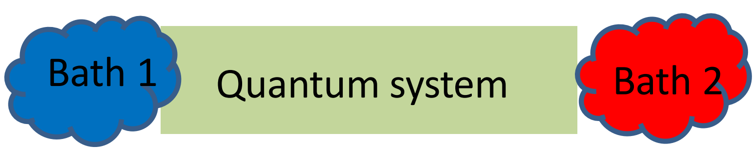
Typical diode characteristic curve with current vs voltage



$\mathcal{J}_f$ Current in forward bias



$\mathcal{J}_r$ Current in reverse bias



Rectification is characterized by

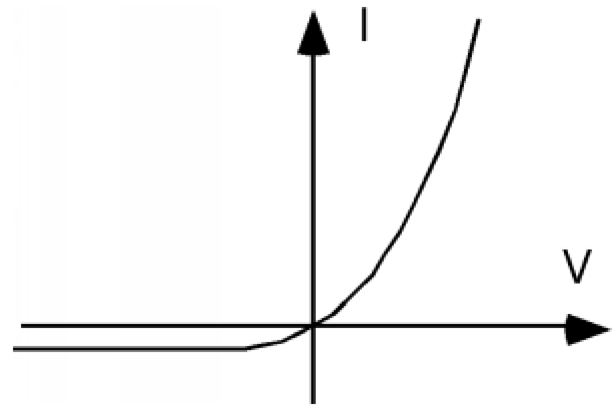
$$\mathcal{R} = -\frac{\mathcal{J}_f}{\mathcal{J}_r}$$

The Contrast is also useful

$$\mathcal{C} = \left| \frac{\mathcal{J}_f + \mathcal{J}_r}{\mathcal{J}_f - \mathcal{J}_r} \right|$$

Perfect spin current rectifier

Typical diode characteristic curve with current vs voltage



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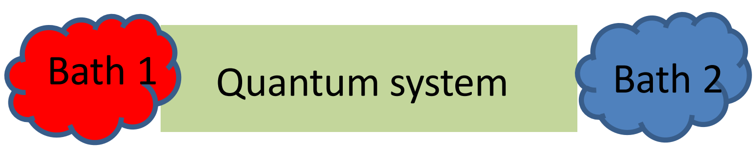

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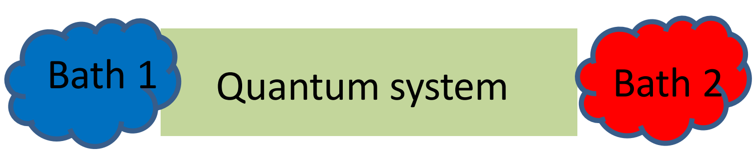


Rectification is characterized by

$$\mathcal{R} = -\frac{\mathcal{J}_f}{\mathcal{J}_r} \quad \to \infty$$

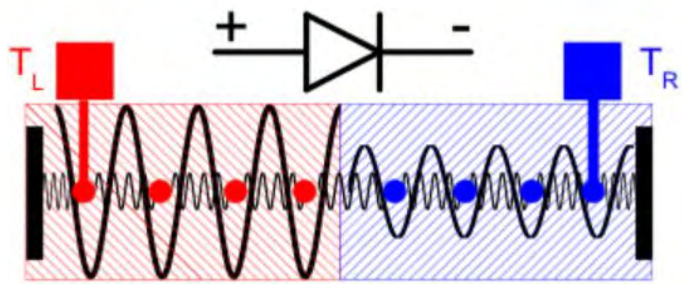
The Contrast is also useful

$$\mathcal{C} = \left| \frac{\mathcal{J}_f + \mathcal{J}_r}{\mathcal{J}_f - \mathcal{J}_r} \right| \quad \to 1$$

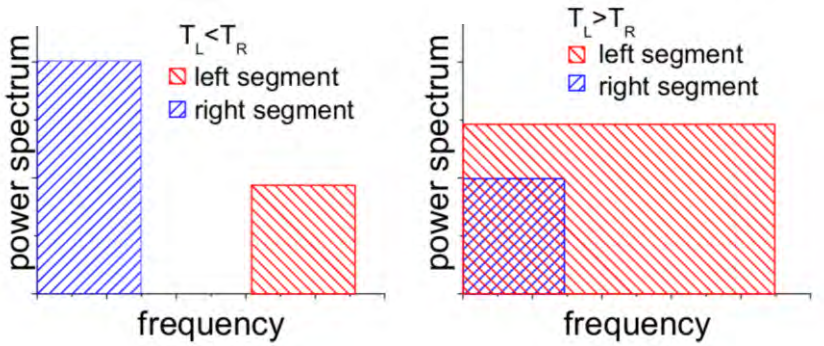
for perfect diode

Perfect spin current rectifier

Consider a classical chain of particles with **nonlinear** couplings and reflection symmetry broken.



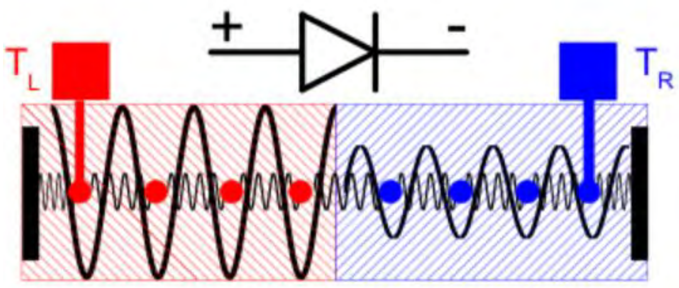
These ingredients allow a diode to function.



Terraneo et al. PRL (2002)
Li et al PRL (2004)
…
Li et al. Rev Mod Phys (2012)
…

Perfect spin current rectifier

Consider a classical chain of particles with **nonlinear** couplings and reflection symmetry broken.



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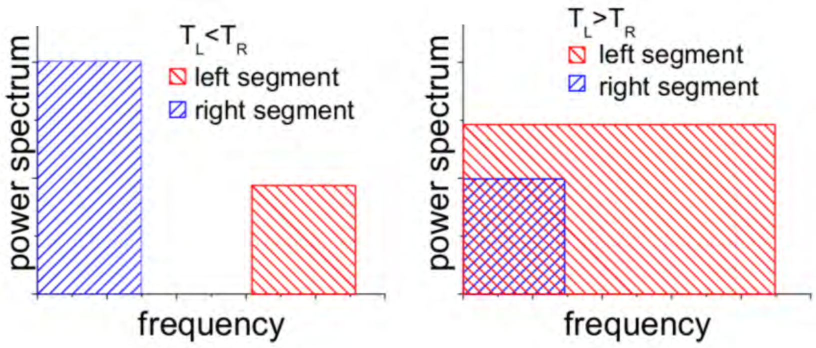


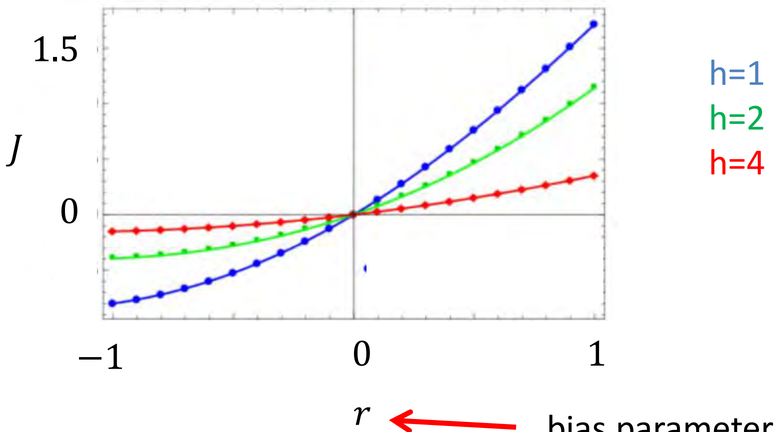
Terraneo et al. PRL (2002)
Li et al PRL (2004)
...
Li et al. Rev Mod Phys (2012)
...

It is natural to try to understand what happens in the quantum regime
nonlinear → strongly interacting

Perfect spin current rectifier

Examples

Rectification in XXZ chain (3 spins) with transverse field
Landi et al PRE (2014)



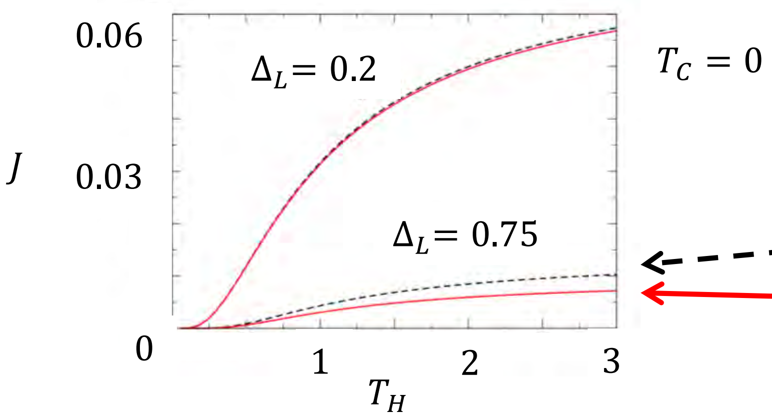
bias parameter

Optimal rectification
Werlang et al PRL (2014)

$$H_S = \frac{h}{2}\,\sigma_z^L + \frac{\Delta}{2}\,\sigma_z^L\sigma_z^R$$

also works from D. Segal, A. Dhar ...

Thermal transport in one-dimensional spin heterostructures
Arrachea et al PRB (2009)



forward bias

reverse bias

XX chain coupled to XY chain and magnetic field in baths

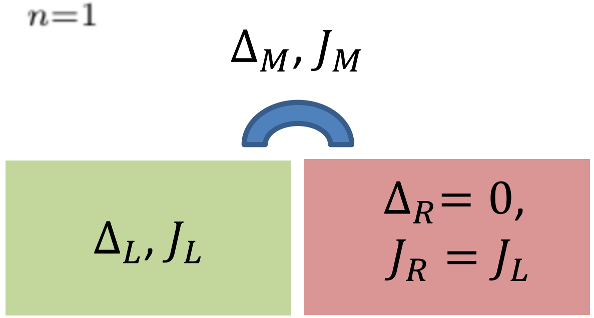
Perfect spin current rectifier

We focus on larger quantum spin chains and we focus on the role of the anisotropy.
No external magnetic fields.

AnIsotropy
Interaction

Segmented XXZ chain

$$\hat{H} = \sum_{n=1}^{N-1} \left[J_n (\hat{\sigma}_n^x \hat{\sigma}_{n+1}^x + \hat{\sigma}_n^y \hat{\sigma}_{n+1}^y) + \Delta_n \hat{\sigma}_n^z \hat{\sigma}_{n+1}^z \right]$$



$\Delta_n = \Delta_L$	$J_n = J_L$	**Interacting** left-half of the chain
$\Delta_n = \Delta_R = 0$	$J_n = J_R$	**Non-interacting** Right-half
$\Delta_n = \Delta_M = 0$	$J_n = J_M$	Junction of two half-chains

Perfect spin current rectifier

We focus on larger quantum spin chains and we focus on the role of the anisotropy.
No external magnetic fields.
We describe the evolution of the system by

$$\frac{d\hat{\rho}}{dt} = \mathcal{L}(\hat{\rho}) = -\frac{\mathrm{i}}{\hbar}[\hat{H}, \hat{\rho}] + \sum_{n=1,N} \mathcal{D}_n(\hat{\rho})$$

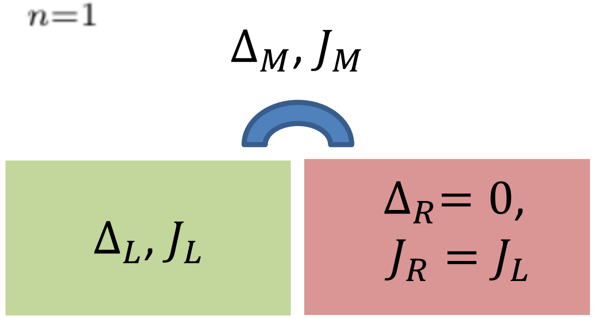
$$\mathcal{D}_n(\hat{\rho}) = \gamma \left[\lambda_n \left(\hat{\sigma}_n^+ \hat{\rho} \hat{\sigma}_n^- - 1/2 \left\{\hat{\sigma}_n^- \hat{\sigma}_n^+, \hat{\rho}\right\}\right) + (1-\lambda_n) \left(\hat{\sigma}_n^- \hat{\rho} \hat{\sigma}_n^+ - 1/2 \left\{\hat{\sigma}_n^+ \hat{\sigma}_n^-, \hat{\rho}\right\}\right)\right]$$

(non-equilibrium) spin baths
They set the local magnetization

AnIsotropy
Interaction

Segmented XXZ chain

$$\hat{H} = \sum_{n=1}^{N-1} \left[J_n (\hat{\sigma}_n^x \hat{\sigma}_{n+1}^x + \hat{\sigma}_n^y \hat{\sigma}_{n+1}^y) + \Delta_n \hat{\sigma}_n^z \hat{\sigma}_{n+1}^z\right]$$



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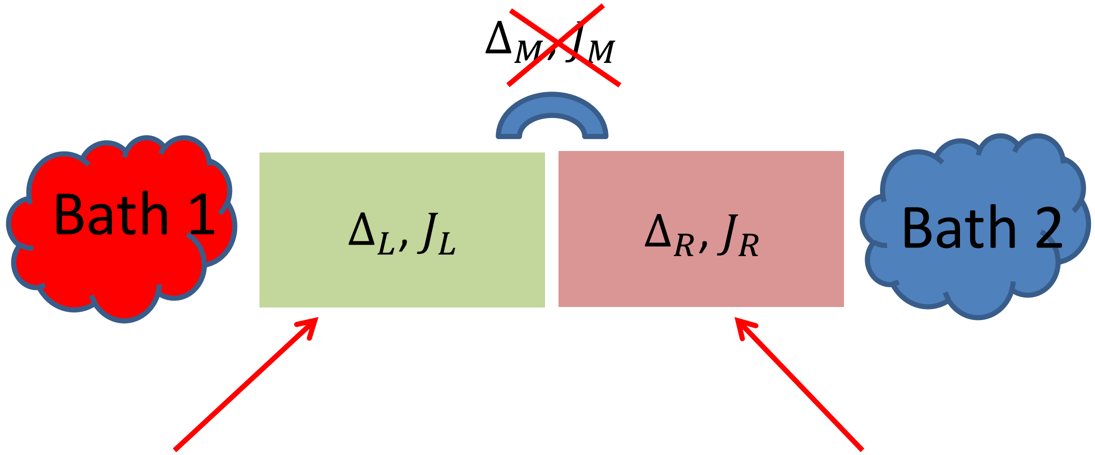
Perfect spin current rectifier

Segmented XXZ chain



Forward bias

$$\boxed{\hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow| \right)/2}$$

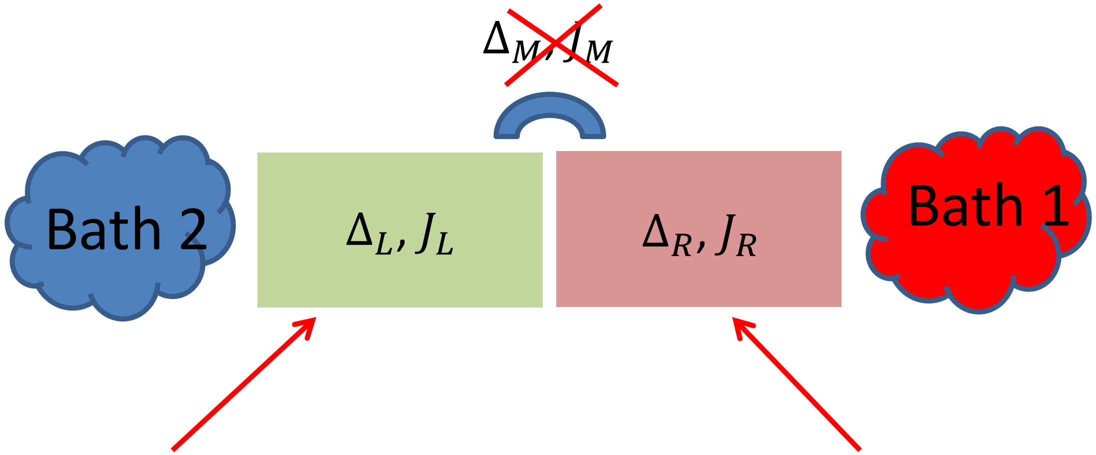
$$\boxed{\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow|}$$

Infinite temperature

Fully polarized

Perfect spin current rectifier

Segmented XXZ chain



Forward bias

$\boxed{\hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow| \right)/2}$ $\boxed{\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow|}$

Infinite temperature | Fully polarized

Reverse bias

$\boxed{\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow|}$ $\boxed{\hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow| \right)/2}$

Fully polarized | Infinite temperature

Perfect spin current rectifier

Let us examine **currents**, **rectification** and **contrast** as function of anisotropy and chain length

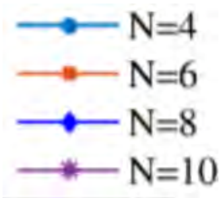
Segmented XXZ chain

$\Delta_M = 0, J_M = 0.1 J_L$

Δ_L, J_L | $\Delta_R = 0, J_R$

$\Delta_R = 0$

$J_L = J_R$



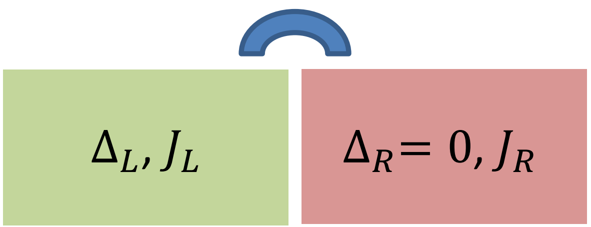
$$\mathcal{R} = -\frac{\mathcal{J}_f}{\mathcal{J}_r}$$ **Rectification**

$$\mathcal{C} = \left|\frac{\mathcal{J}_f + \mathcal{J}_r}{\mathcal{J}_f - \mathcal{J}_r}\right|$$ **Contrast**

Perfect spin current rectifier

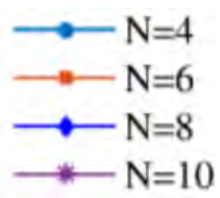
Segmented XXZ chain

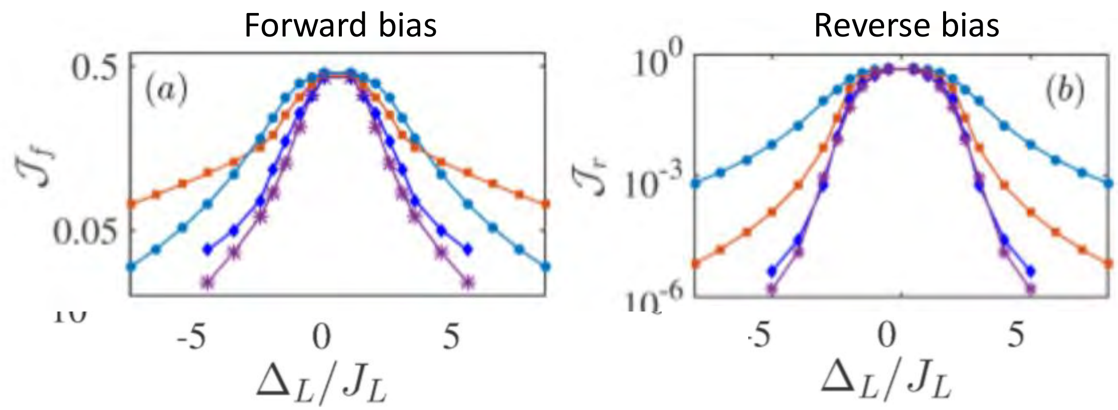
$\Delta_M = 0, J_M = 0.1 J_L$



$\boxed{\Delta_R = 0 \quad J_L = J_R}$

Let us examine **currents**, **rectification** and **contrast** as function of anisotropy and chain length





Forward and Reverse bias **currents** vs anisotropy of left half

$$\mathcal{R} = -\frac{\mathcal{J}_f}{\mathcal{J}_r}$$

Rectification

$$\mathcal{C} = \left| \frac{\mathcal{J}_f + \mathcal{J}_r}{\mathcal{J}_f - \mathcal{J}_r} \right|$$

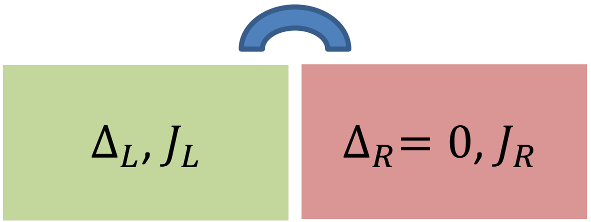
Contrast

Perfect spin current rectifier

Let us examine **currents**, **rectification** and **contrast** as function of anisotropy and chain length

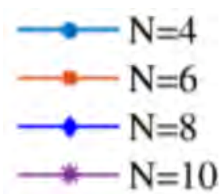
Segmented XXZ chain

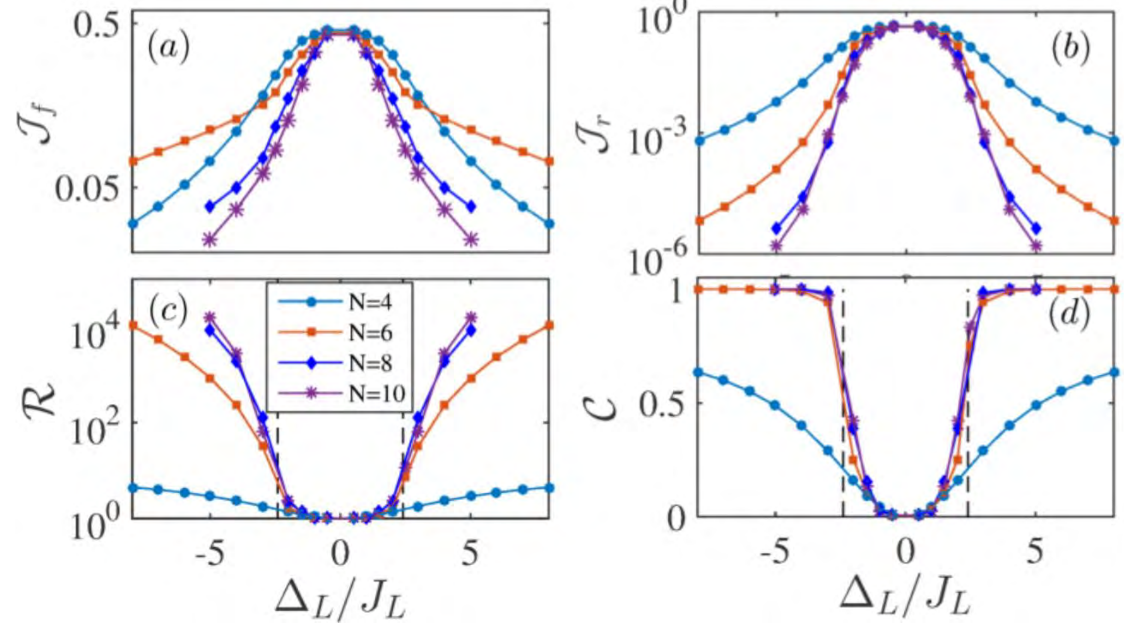
$\Delta_M = 0, J_M = 0.1 J_L$



$\Delta_R = 0$

$J_L = J_R$





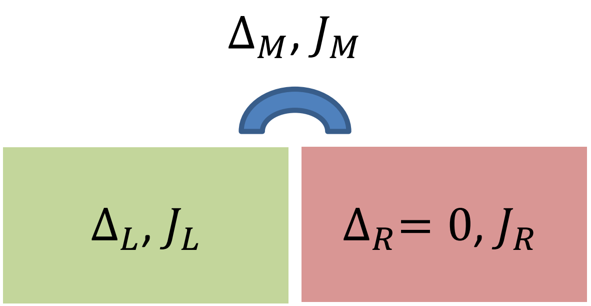
$$\mathcal{R} = -\frac{\mathcal{J}_f}{\mathcal{J}_r}$$ **Rectification**

$$\mathcal{C} = \left| \frac{\mathcal{J}_f + \mathcal{J}_r}{\mathcal{J}_f - \mathcal{J}_r} \right|$$ **Contrast**

Rectification and **Contrast** vs anisotropy of left half

Perfect spin current rectifier

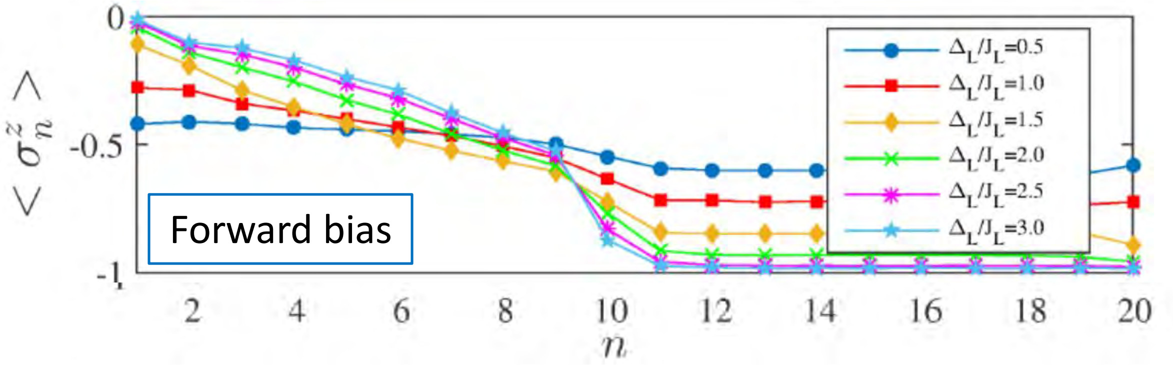
Segmented XXZ chain



$\Delta_R = 0$

$J_L = J_R$

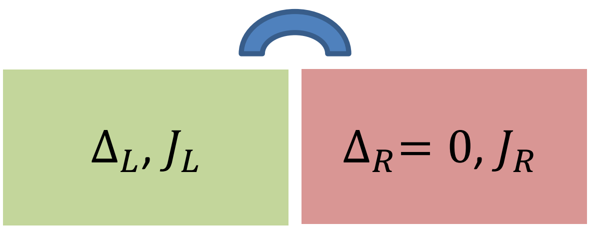
Magnetization profiles



Perfect spin current rectifier

Segmented XXZ chain

Δ_M, J_M



$\Delta_R = 0$

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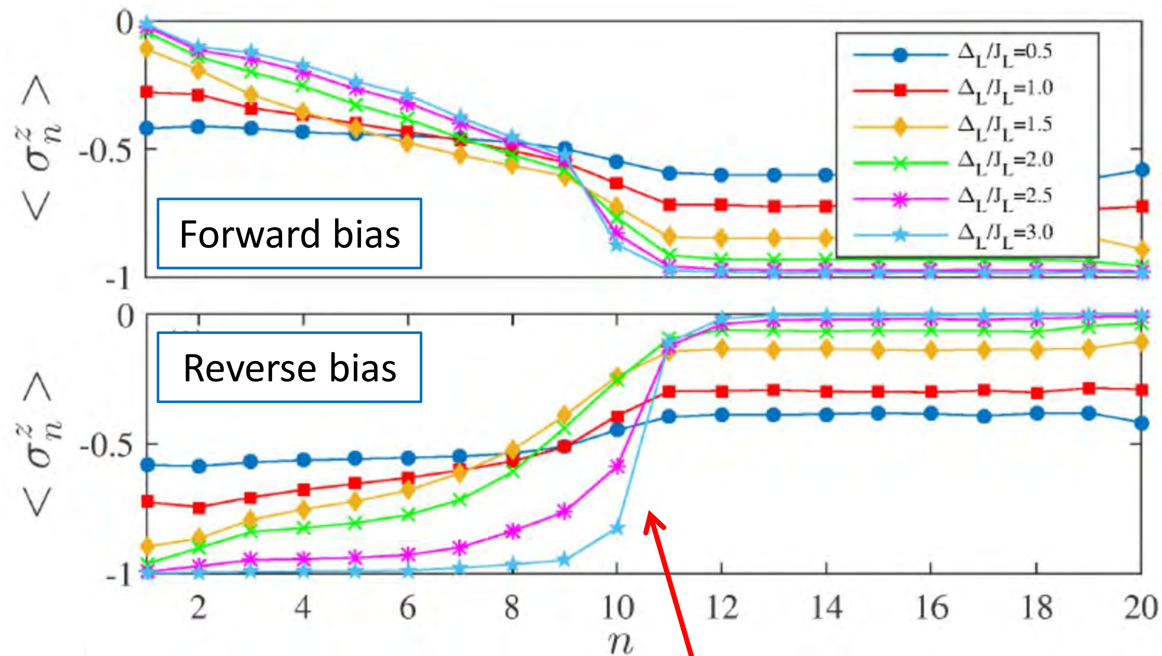
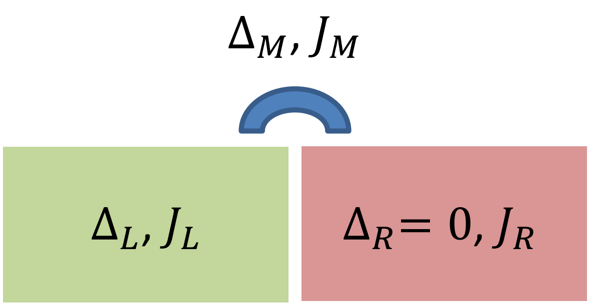
Magnetization profiles



Insulating?
Which is the **critical value of anisotropy**?
What is the **mechanism** behind such good rectification?

Perfect spin current rectifier

Segmented XXZ chain



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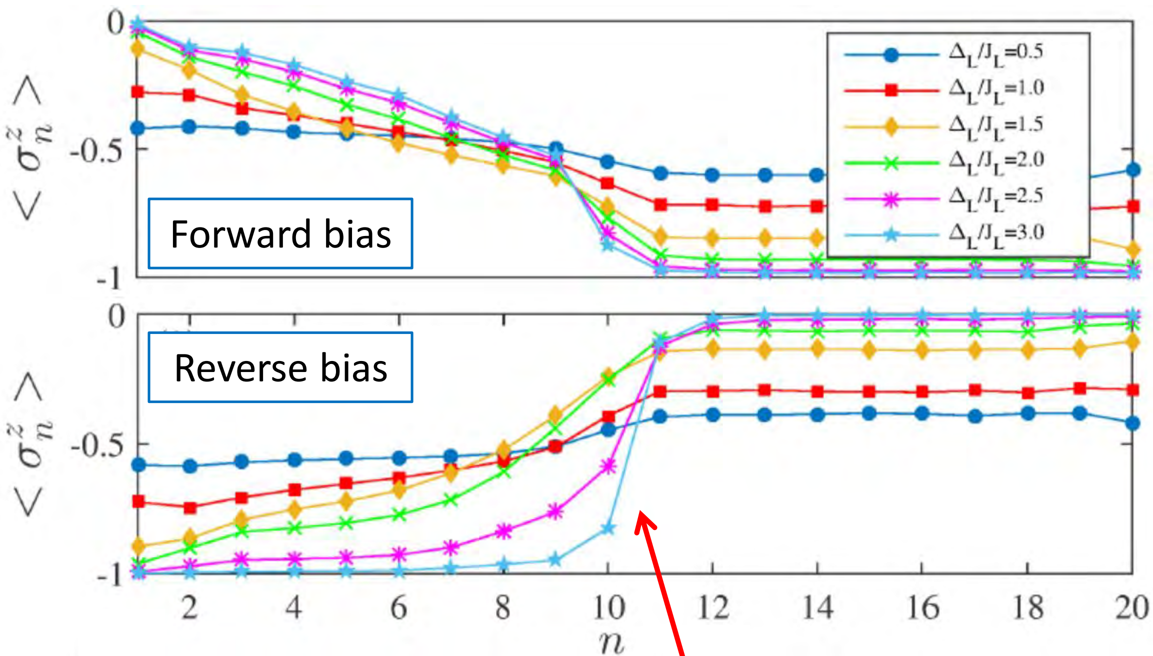
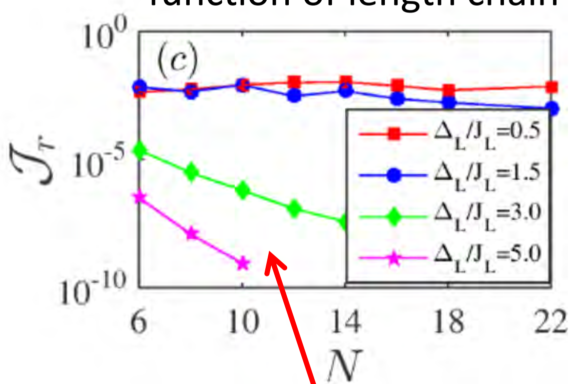


Reverse current as function of length chain



Smaller anisotropy

Larger anisotropy

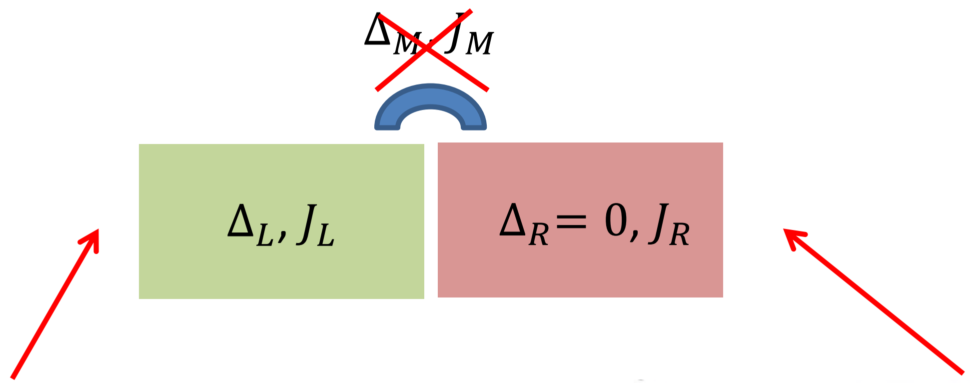
Insulating?

Which is the **critical value of anisotropy**?

What is the **mechanism** behind such good rectification?

Perfect spin current rectifier

Let us consider the reverse bias case

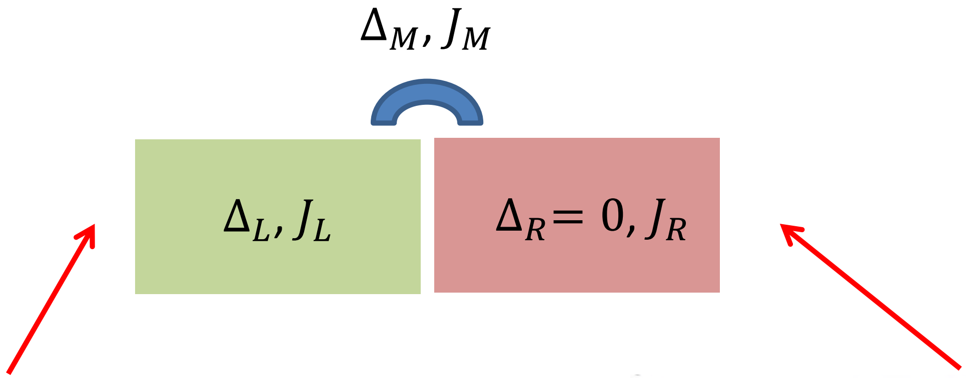


$$\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow|$$

$$\hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow|\right)/2$$

Perfect spin current rectifier

Let us consider the reverse bias case



$$\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow| \qquad \hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow|\right)/2$$

Can a spin flip $\sigma^+_{N/2}\,\sigma^-_{N/2+1}$ be generated at the boundary without energy cost?

Perfect spin current rectifier

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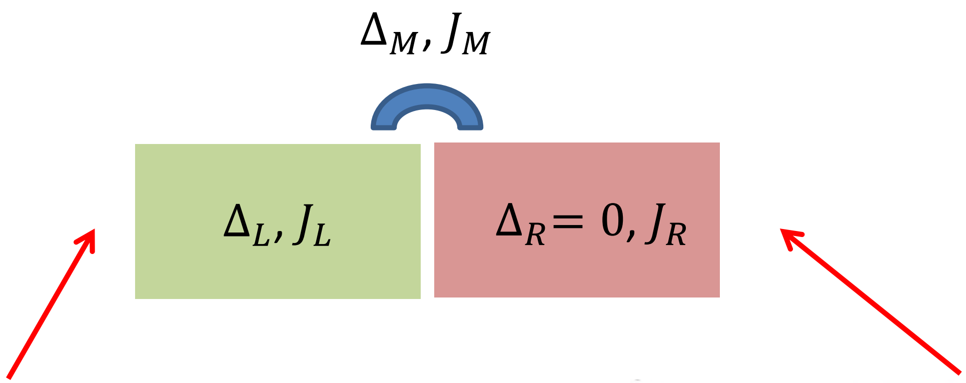


$\hat{\rho}_{ss,\lambda_j=0} = \bigotimes_n |\downarrow\rangle_n\langle\downarrow|$ $\hat{\rho}_{ss,\lambda_j=0.5} = \bigotimes_n \left(|\uparrow\rangle_n\langle\uparrow| + |\downarrow\rangle_n\langle\downarrow|\right)/2$

Can a spin flip $\sigma^+_{N/2}\ \sigma^-_{N/2+1}$ be generated at the boundary without energy cost?

We analyse the excitation spectrum of each half of the chain.
The left side is given by the eigenvalues of

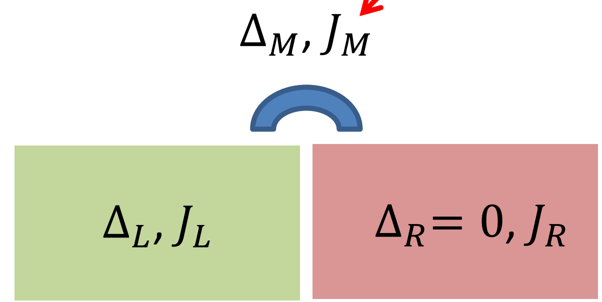
$$\mathbb{M}(\Delta) = \begin{bmatrix} -2\Delta_L & 2J_L & 0 & \dots & \dots & \dots \\ 2J_L & -4\Delta_L & 2J_L & 0 & \dots & \dots \\ 0 & 2J_L & -4\Delta_L & 2J_L & 0 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & 0 & 2J_L & -4\Delta_L & 2J_L \\ \dots & \dots & 0 & 0 & 2J_L & -2\Delta_L \end{bmatrix}$$

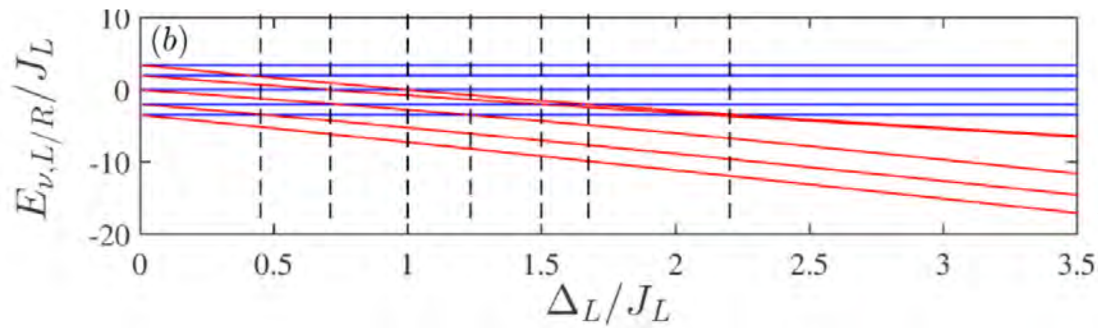
If there is an **energy gap** in the **overall system** (left and right halves), it can become **insulating**!

Perfect spin current rectifier

very small

We test this in detail on a small system of 10 spins





Spectrum of right half of the chain

Spectrum of left half of the chain

Perfect spin current rectifier

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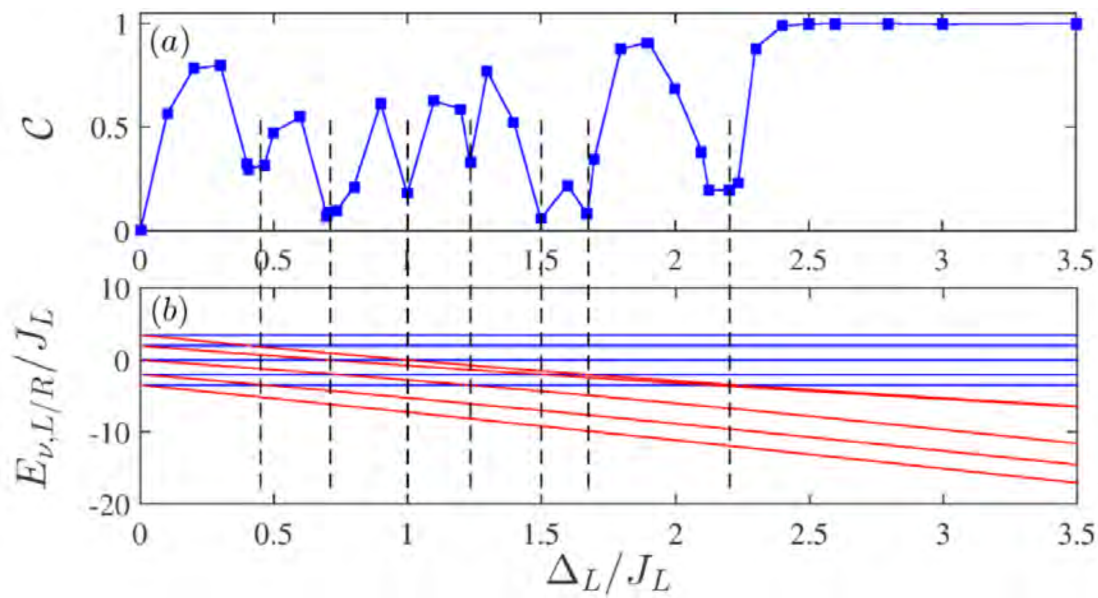

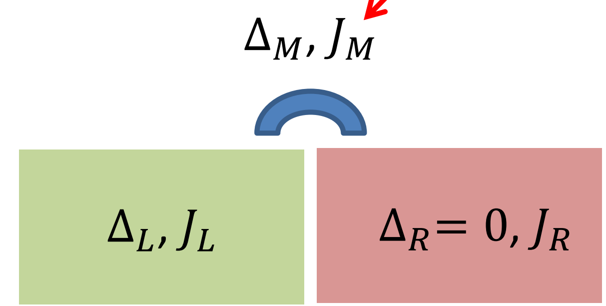

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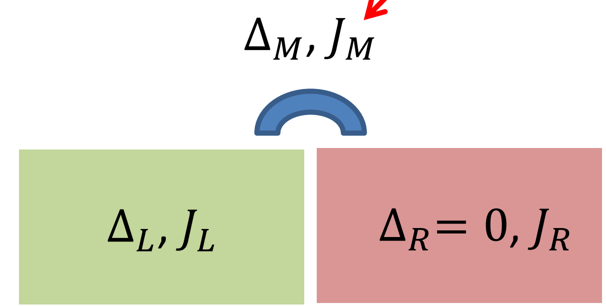

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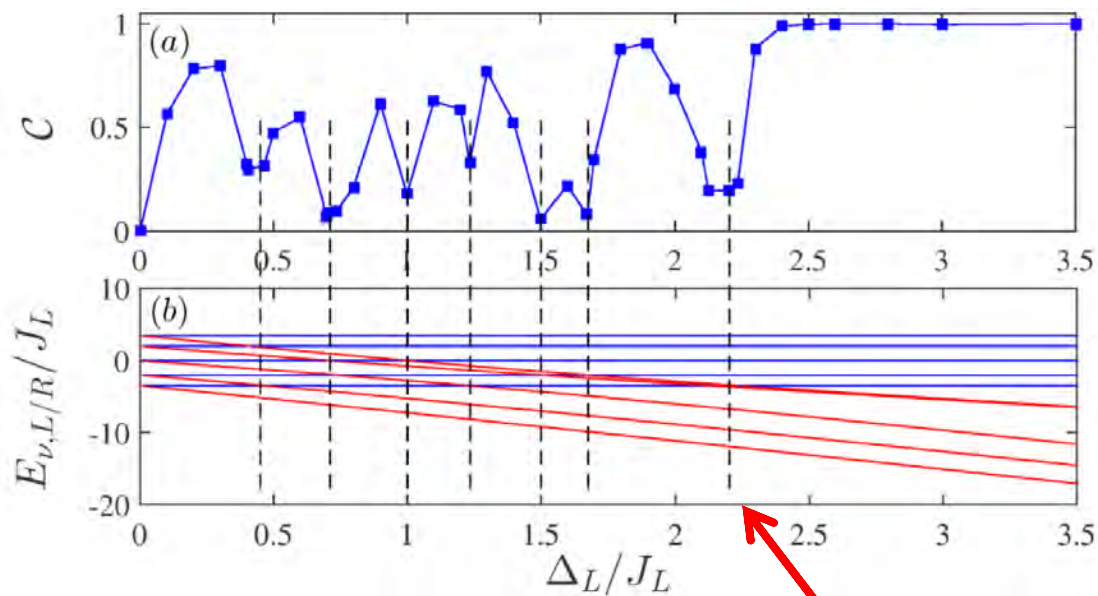

Spectrum of right half of the chain

Spectrum of left half of the chain

Beyond this point the contrast is always large

For large systems the critical value is

$$\Delta_{L,c} = J_R + \sqrt{J_R^2 + J_L^2}.$$

Perfect spin current rectifier

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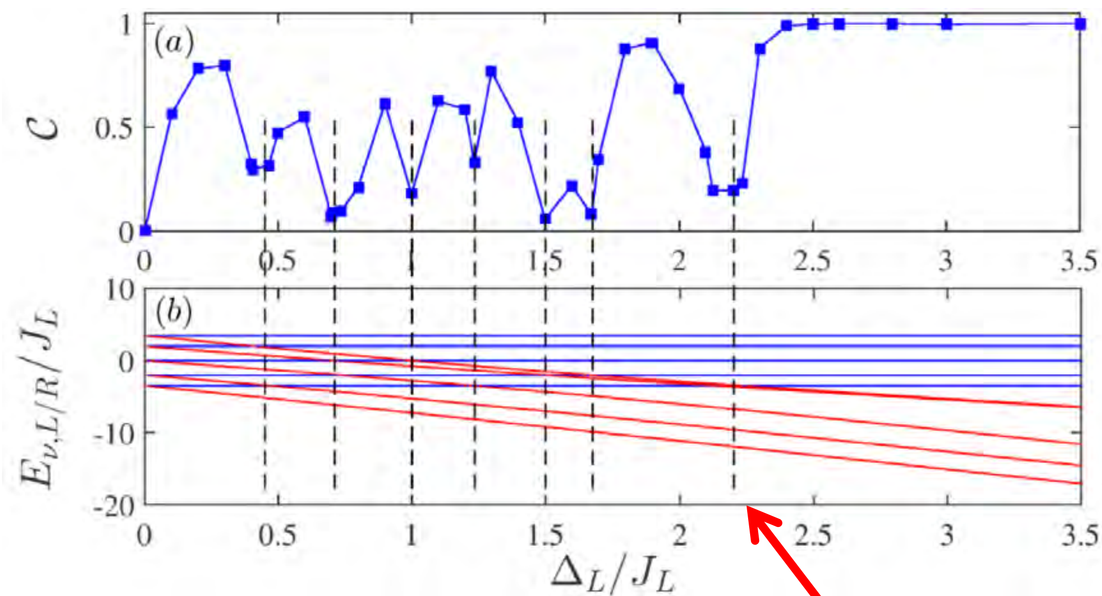

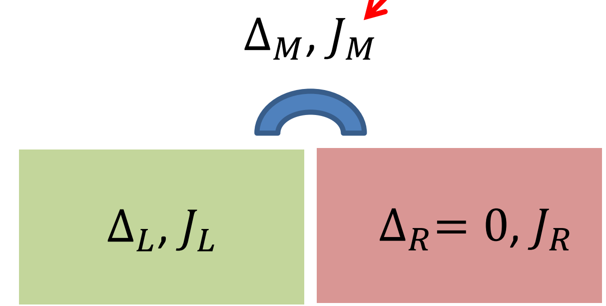

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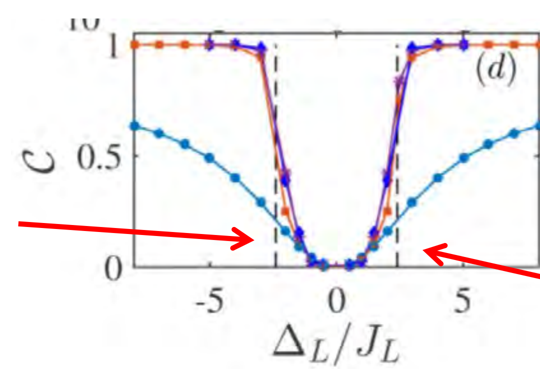
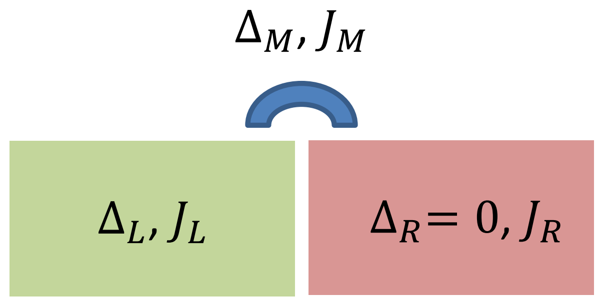


Small system with large J_M

$1 + \sqrt{2}$

Perfect spin current rectifier

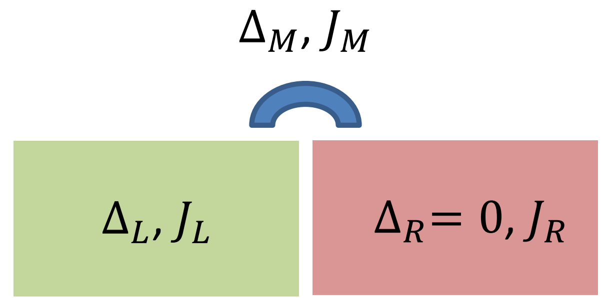


Ljubotina et al. Nat Comm 2017
Mascarenhas et al Quantum 2017
Biella et al. PRB 2016
Ponomarev et al. PRL 2011
…

$\bigotimes_n \left(|\uparrow\rangle_n \langle\uparrow| + |\downarrow\rangle_n \langle\downarrow| \right)/2$ $\qquad$ $\bigotimes_n |\downarrow\rangle_n \langle\downarrow|$

We prepare two long chains in either the infinite temperature state or fully polarized state. We then connect them and measure the time t^* it takes for the spin at the interface to change from $\left\langle \sigma^z_{L/2}(0) \right\rangle = -1$ to $\left\langle \sigma^z_{L/2}(t^*) \right\rangle = -0.99$

Perfect spin current rectifier



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…

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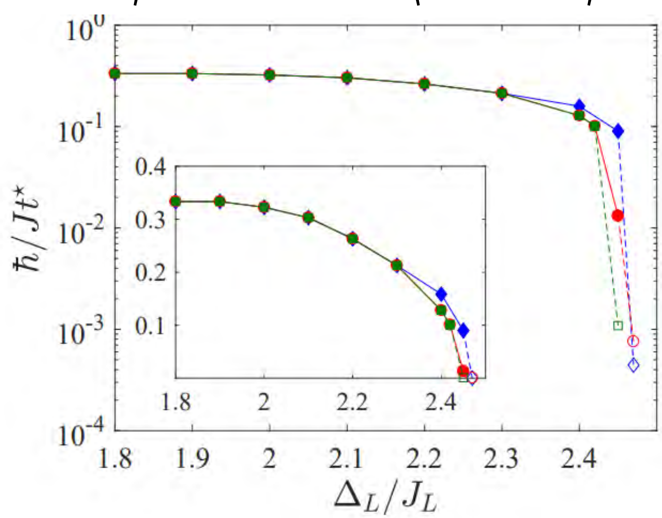
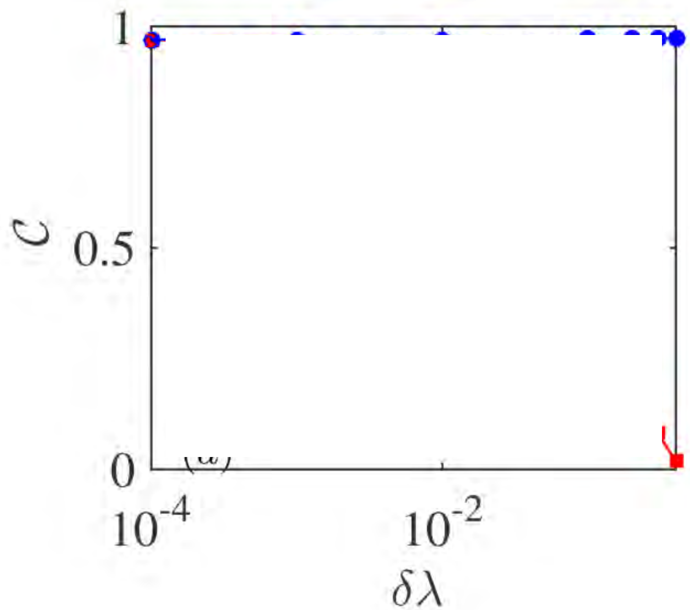
N=20
N=50
N=100



$1/t^*$ decreases abruptly as Δ_L/J_L approaches $1 + \sqrt{2}$

Perfect spin current rectifier

What about the stability of the effect?
We add a deviation of the bath parameter λ only on one bath and check how large the contrast remains.



The contrast is very stable when the portion close to infinite temperature is changed to a lower T.
Not as stable for the portion fully polarized.

Deviation of the bath parameter λ from the ideal scenario of either **fully polarized** or from **infinite temperature**.

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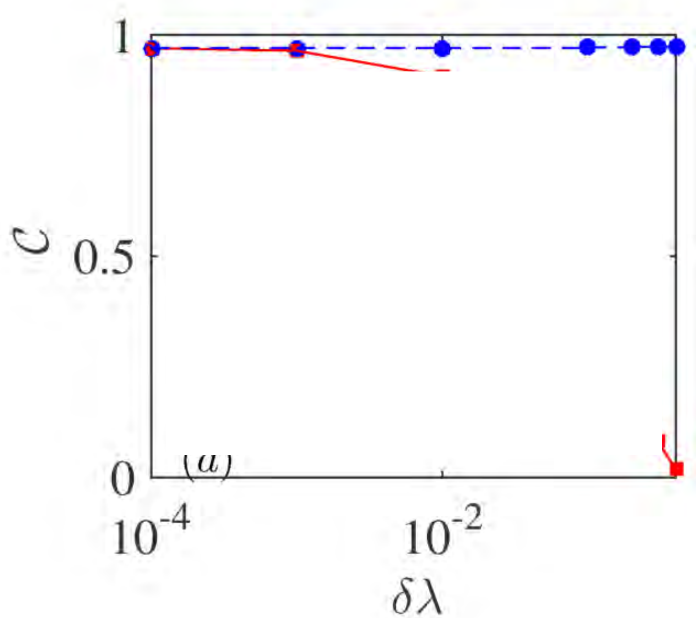

Modifying λ for the **infinite temperature** portion

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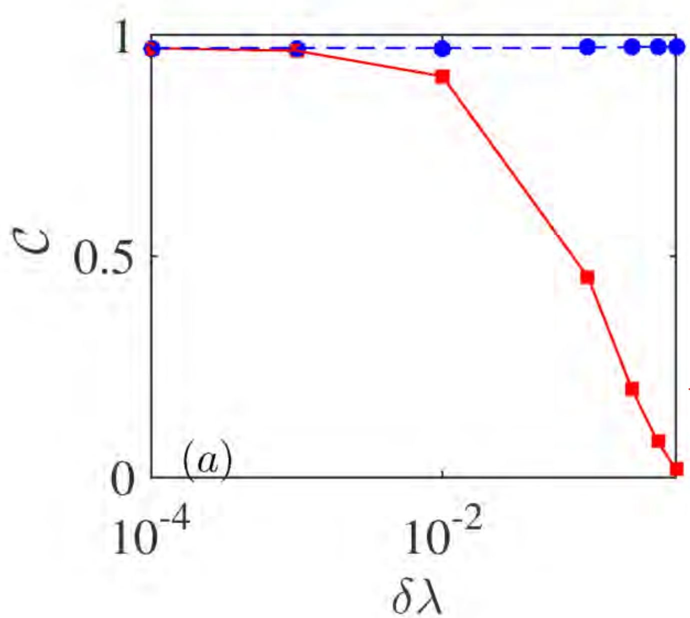

Modifying λ for the **infinite temperature** portion

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Perfect spin current rectifier

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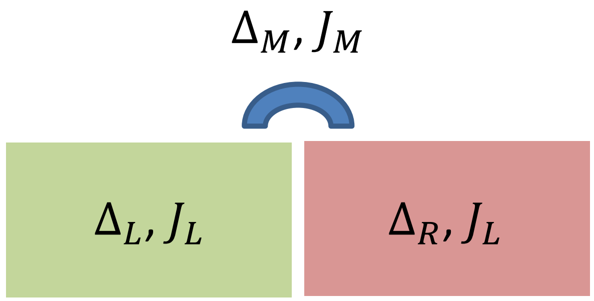
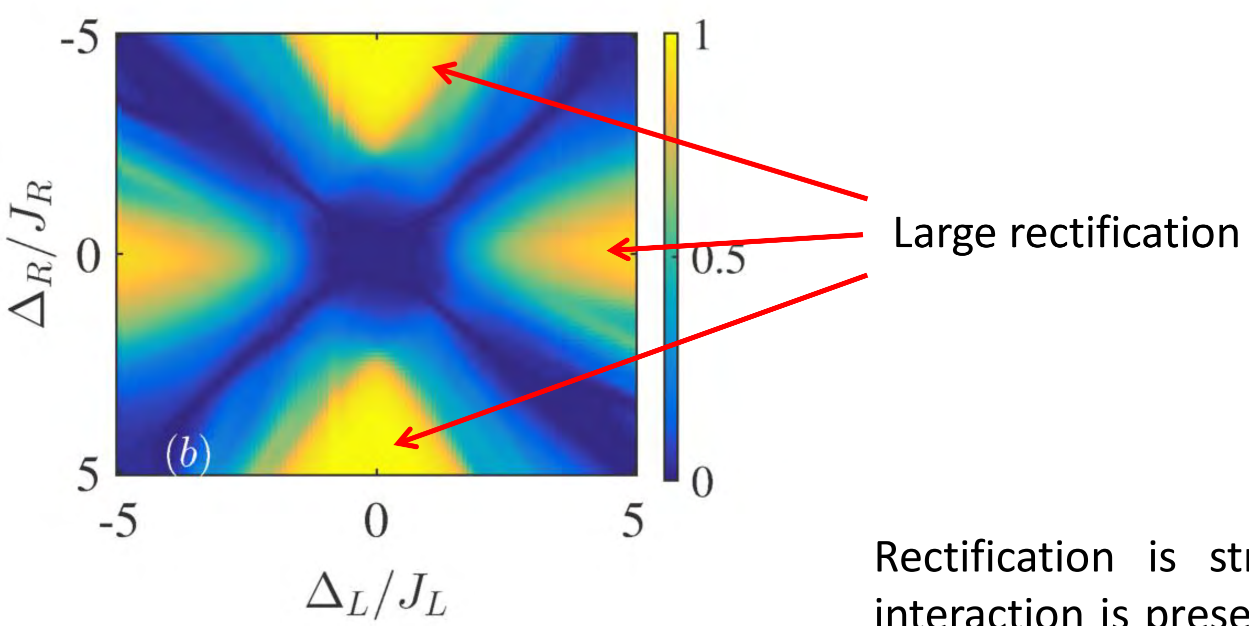


Contrast

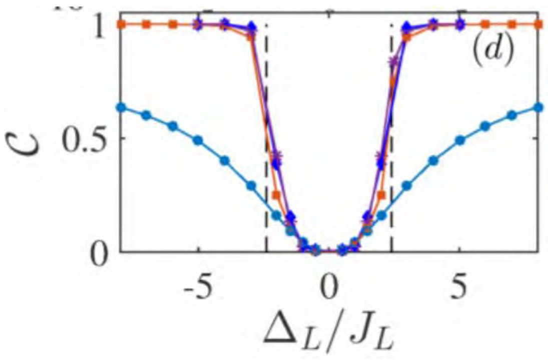


Rectification is strongest when interaction is present only in half of the chain.

Perfect spin current rectifier

We have shown

- a system which, thanks to strong interactions, approaches the limit of a perfect rectifier.
- described the mechanism
- discuss the stability



Work in progress

- use different types of interaction
- can it be used to rectify heat? With what performance?
- …

Perfect spin current rectifier

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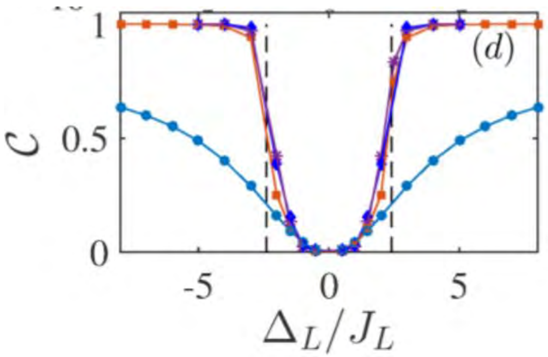


Work in progress

- use different types of interaction
- can it be used to rectify heat? With what performance?
- …

Stay tuned!!

Plan of the presentation

1) Perfect spin rectifier

Physical Review Letters (2018)

V. Balachandran

E. Pereira

G. Benenti

G. Casati

+ D.P.

2) Interplay between disorder, strong interactions and tailored dissipation

Physical Review B, 97, 140201(R) (2018)

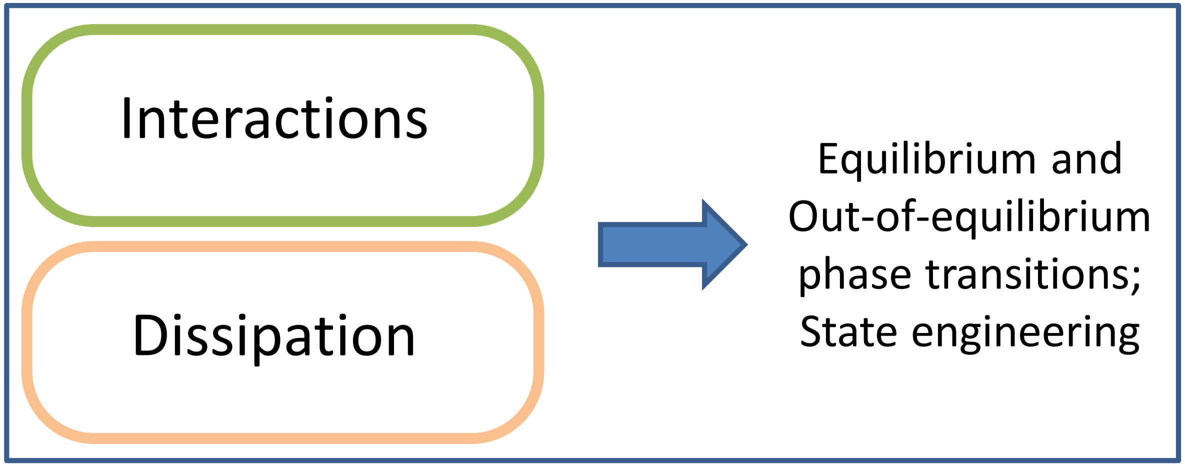
X. Xu

C. Guo

+ D.P.

Conclusions and Outlook

Interaction + dissipation + disorder



Interaction + dissipation + disorder

Interactions

Dissipation

→ Equilibrium and Out-of-equilibrium phase transitions; State engineering

What are the effects of

Disorder

Interaction + dissipation + disorder

Interactions

Dissipation

Equilibrium and Out-of-equilibrium phase transitions; State engineering

What are the effects of

Disorder

Interactions

Disorder

Many body localization, Mobility edges

Interaction + dissipation + disorder

Interactions

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Equilibrium and
Out-of-equilibrium
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What are the effects of

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Interactions

Disorder

Many body
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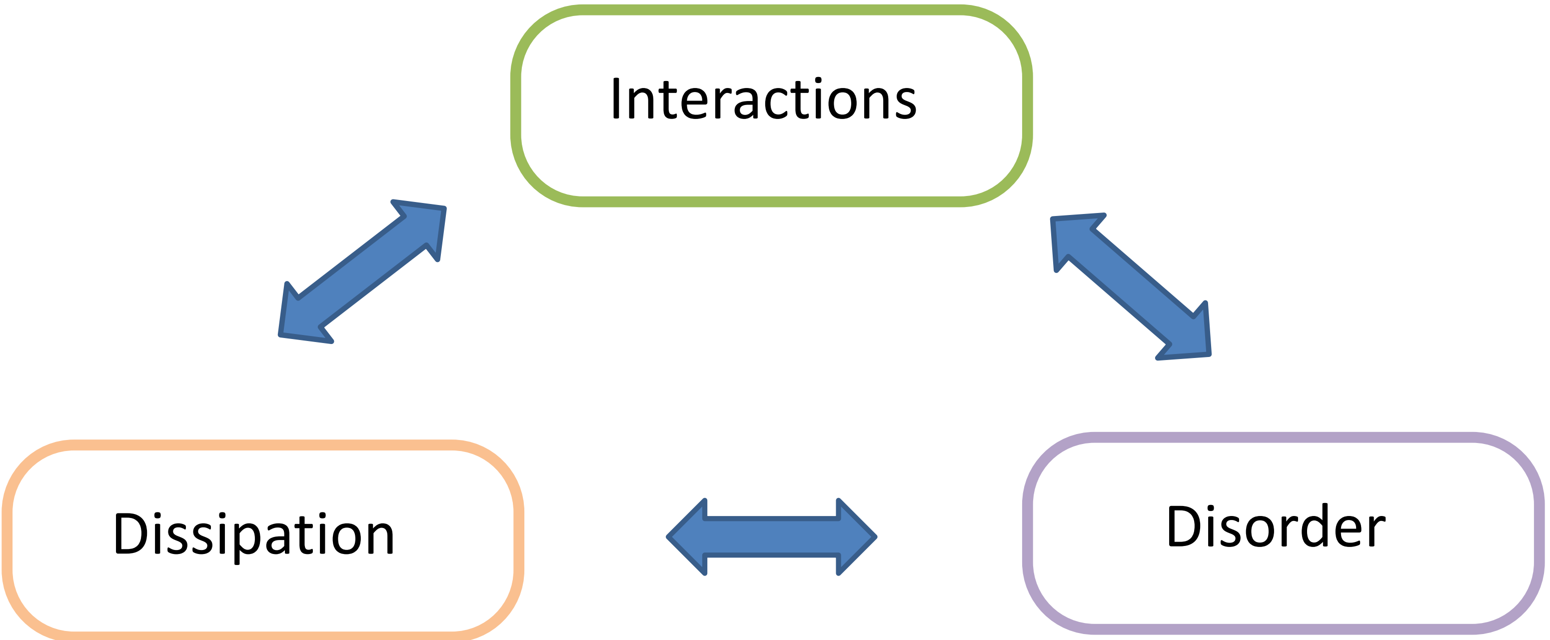
What are the effects of

Dissipation

Interaction + dissipation + disorder



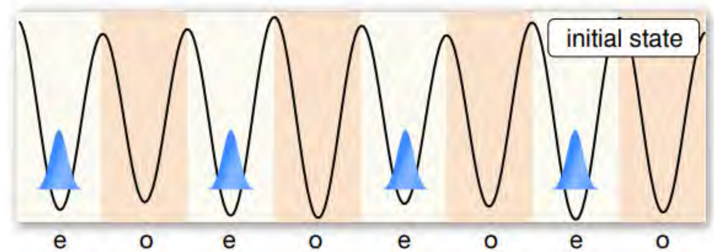
With a particular focus on engineered baths which tend to counter disorder.

X. Xu, C. Guo, DP, Phys. Rev B Rapid (2018)

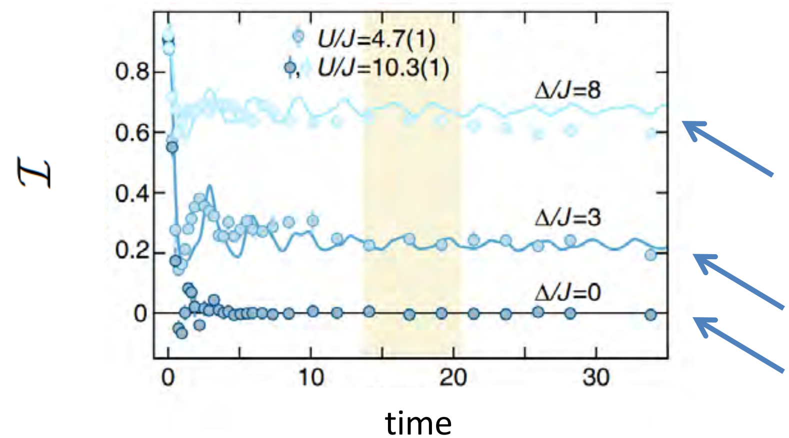
Background: Many body localization and probes

Many body quantum systems in presence of disorder can be localized.

D.M. Basko et al. Ann. Phys. (2006)



$$\mathcal{I} = \frac{N_e - N_o}{N_e + N_o},$$



Schreiber et al., Science (2015)

Some EXPERIMENTS

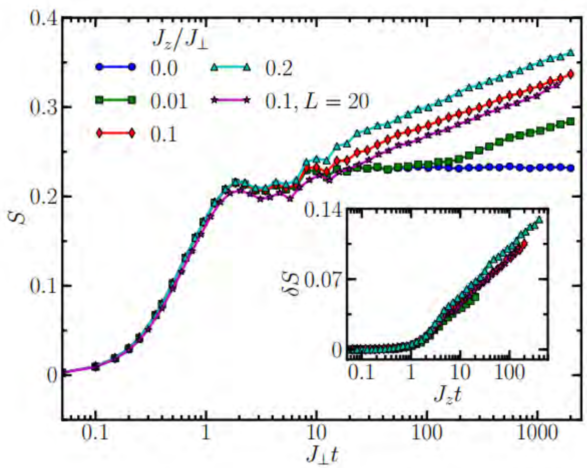
C. D'Errico et al., PRL (2014)
Schreiber et al., Science (2015)
Smith, et al., Nat. Phys. (2016)
Bordia, et al. PRL (2016)
Choi et al., Science (2016)
Bordia et al., PRL (2016)
Bordia et al., Nat. Phys. (2017)
Roushan et al., arXiv:1709.07108
Bordia et al. arxiv:1704.03063

Atoms, ions, disordered or quasiperiodic, periodically driven, 1D, 2D, dissipative

Some REVIEWS

R Nandkishore, DA Huse, Annu. Rev. Condens. Matter Phys. (2015)
DA Abanin, Z Papić, Annalen der Physik (2017)

Background: Many body localization and probes



Bardarson et al. PRL (2012)

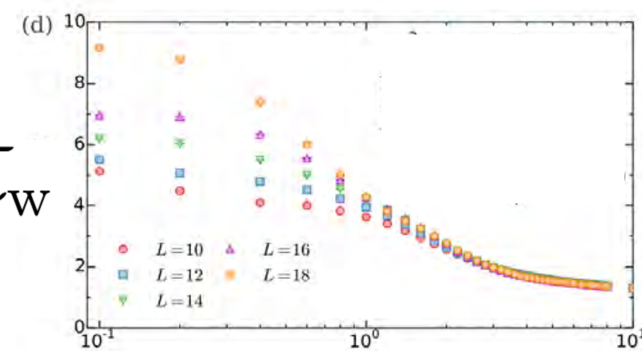
Entanglement entropy grows logarithmically.

$$\rho_{ij} = \langle \psi_n | c_i^\dagger c_j | \psi_n \rangle \qquad \rho | \phi_\alpha \rangle = n_\alpha | \phi_\alpha \rangle$$

$$\mathcal{I}_\mathrm{W} = \sum_{\alpha,l} n_\alpha |\psi_\alpha(l)|^4$$

Inverse participation ratio

$\mathcal{I}_\mathrm{W}$



W disorder

Bera et al., PRL (2015)

Single particle reduced density matrix shows exponentially localized natural orbitals.

Interaction + dissipation + disorder

The physics observed may vary significantly.
For instance:

the MBL system may become delocalized even when coupled to a small system or may localized the other system.

Hyatt et al. PRB (2017)
Nandkishore et al. PRB (2014)
Nandkishore, PRB (2014)
Marino, Nandkishore, arxiv:1712.01923
C. Gross

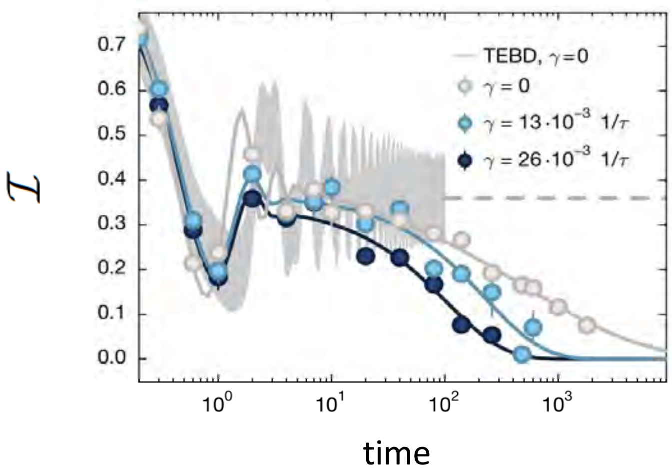
losses and dephasing destroy localization

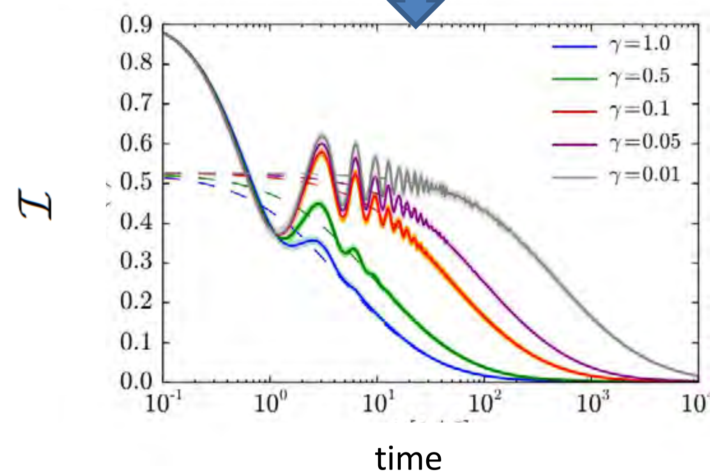
van Nieuwenburg et al. Quantum Sci. Technol. (2018)

Fischer et al. PRL (2016)

$$\mathcal{I} = \frac{N_e - N_o}{N_e + N_o},$$

Luschen et al. Phys. Rev. X (2017)





Interaction + dissipation + disorder

Are there signatures of an interesting interplay between disorder interaction and dissipation in the steady state?

Transport -> Znidaric

Interaction + dissipation + disorder

Are there signatures of an interesting interplay between disorder interaction and dissipation in the steady state?

XXZ chain (Δ/J) + tailored dissipation + disorder (W)

$$\hat{H} = \sum_{l=1}^{L-1} \left[J \left(\hat{\sigma}_l^x \hat{\sigma}_{l+1}^x + \hat{\sigma}_l^y \hat{\sigma}_{l+1}^y \right) + \Delta \hat{\sigma}_l^z \hat{\sigma}_{l+1}^z \right] + \sum_{l=1}^{L} h_l \hat{\sigma}_l^z$$

disorder

We use a model described by a Lindblad master equation

$$\frac{d\hat{\rho}}{dt} = \mathcal{L}[\hat{\rho}] = -\frac{i}{\hbar}[\hat{H}, \hat{\rho}] + \mathcal{D}[\hat{\rho}].$$

where the dissipator has this form

$$\mathcal{D}[\hat{\rho}] = \gamma \sum_{l=1}^{L-1} \left(\hat{V}_{l,l+1} \hat{\rho} \hat{V}_{l,l+1}^{\dagger} - \frac{1}{2} \{ \hat{V}_{l,l+1}^{\dagger} \hat{V}_{l,l+1}, \hat{\rho} \} \right)$$

and the jump operators are

$$\boxed{\hat{V}_{l,l+1} = \left(\hat{\sigma}_l^+ + \hat{\sigma}_{l+1}^+ \right) \left(\hat{\sigma}_l^- - \hat{\sigma}_{l+1}^- \right)}$$

S. Diehl et al. Nature Phys. (2008)

S. Diehl, et al. PRL (2010)

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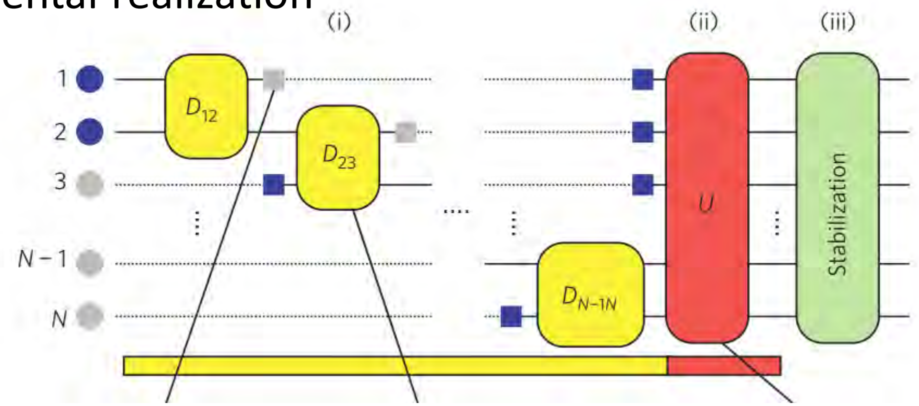
S. Diehl, et al. PRL (2010)

P. Schindler, et al. Nature Physics (2013)

Experimental realization



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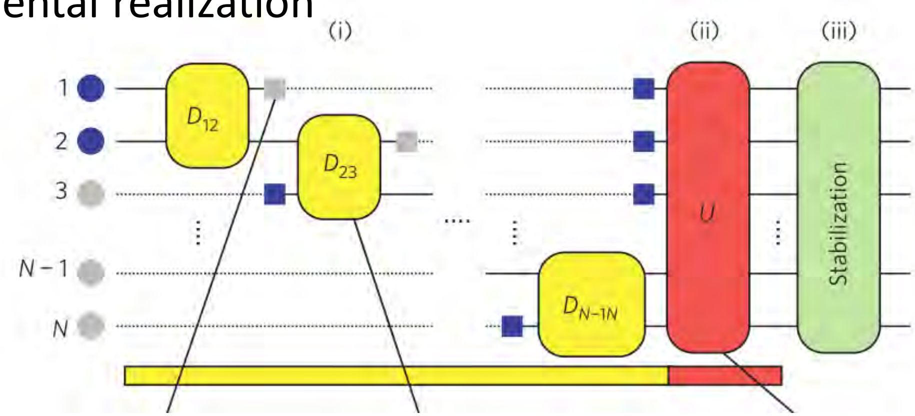

Twin work for XXZ chain (Δ/J) + tailored dissipation + disorder (W)

Vakulchyk et al. arxiv:1709.08882

System + tailored bath: **without disorder**

We can prove that the combination of the dissipator and the symmetries of Hamiltonian impose that the **local magnetization is 0** for every site in the steady state.

In fact $\hat{T} = \otimes_l \hat{\sigma}_l^x \qquad \hat{T}\hat{H}\hat{T} = \hat{H}$ and $\hat{T}\hat{V}_{l,l+1}\hat{T} = -\hat{V}_{l,l+1}$

Imply, for any value of Δ $\boxed{\langle \hat{\sigma}_l^z \rangle = 0}$

For $\Delta = J.$

We can prove that the steady state is a pure Dicke state $\boxed{\hat{\rho}_s = |\psi_S\rangle\langle\psi_S|}$

With $|\psi_S\rangle \propto \left(\sum_{l=1}^{L} \sigma_l^+\right)^{L/2} |\downarrow\rangle^{\otimes L}$ i.e. all possible states at 0 magnetization

System + tailored bath: **with disorder**

What happens when we add (even small) disorder?

We study the local magnetization and its probability distribution P.

$$m_{l,i} = \langle \hat{\sigma}_l^z \rangle_i$$

System + tailored bath: **with disorder**

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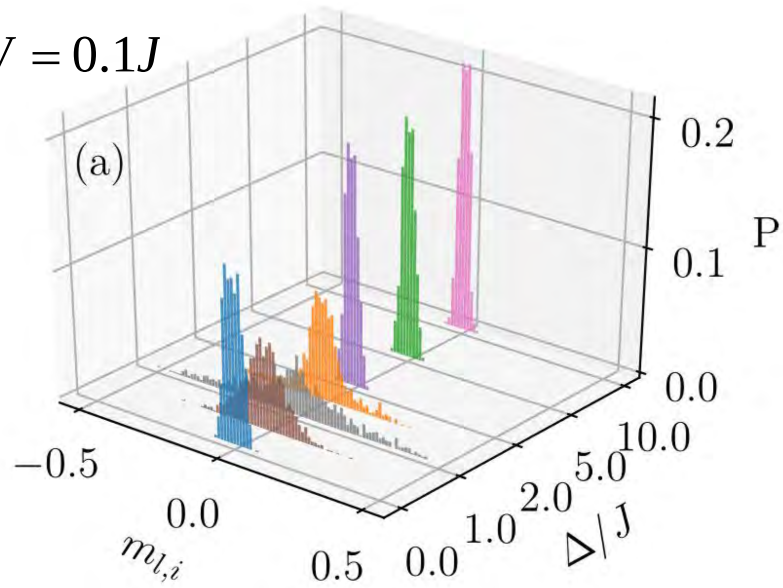
$W = 0.1J$



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Instead of a delta peak distribution now we observe a broad distribution, especially for $\Delta = J$

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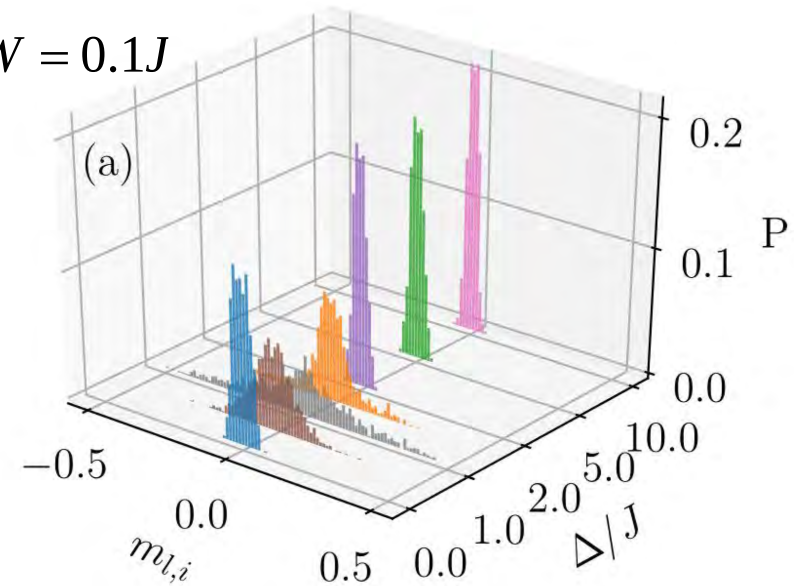

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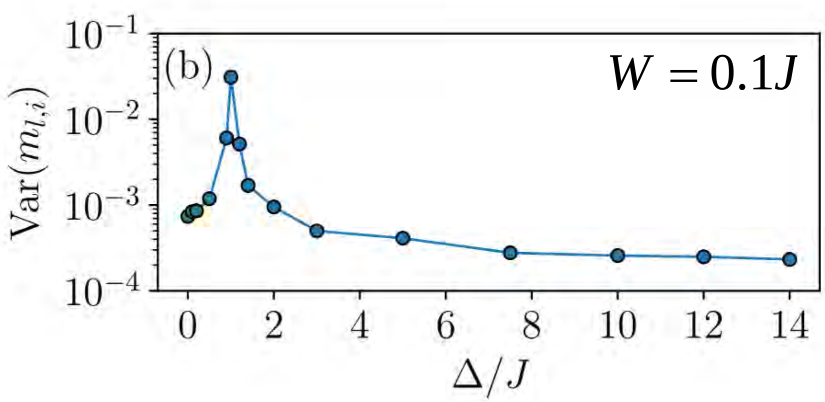

The variance of the distribution has a marked peak exactly at $\Delta = J$

Localization signatures in the steady state

Are there signatures of an interesting interplay between disorder interaction and dissipation in the steady state?

single particle density matrix → eigenvalues and eigenvectors → inverse participation ratio → average over disorder

$\rho_{\mathrm{sp}}^{j,k} = \langle \hat{\sigma}_j^+ \hat{\sigma}_k^- \rangle$

$\rho_{\mathrm{sp}} \psi_\alpha = n_\alpha \psi_\alpha$

$\mathcal{I}_{\mathrm{w}} = \sum_{\alpha,l} n_\alpha |\psi_\alpha(l)|^4$

$\bar{\mathcal{I}}_{\mathrm{w}}$

Bera et al., PRL (2015)

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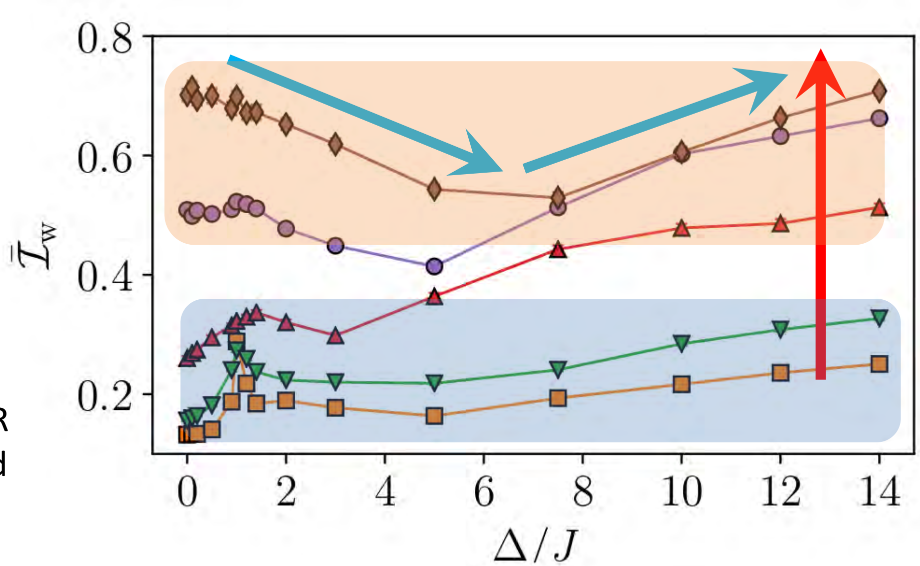
IPR **non-monotonous** with interaction strength.

For **strong disorder** the IPR can large both at weak and strong interaction.



W → disorder strength

$W = 10J$

$W = 5J$

$W = 2J$

$W = 0.5J$

$W = 0.1J$

Direction of **red arrow** for increasing strength of disorder.

X. Xu, C. Guo, DP, Phys. Rev B Rapid (2018)

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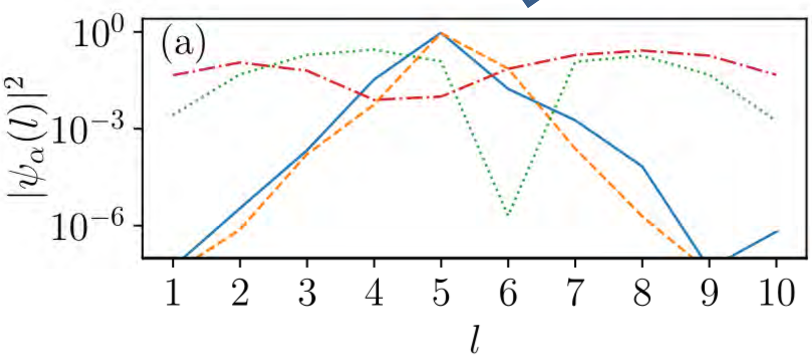
Are there signatures of an interesting interplay between disorder interaction and dissipation in the steady state?

single particle density matrix → eigenvalues and eigenvectors → inverse participation ratio → average over disorder

$$\rho_{\rm sp}^{j,k} = \langle \hat{\sigma}_j^+ \hat{\sigma}_k^- \rangle \qquad \rho_{\rm sp}\psi_\alpha = n_\alpha \psi_\alpha \qquad \mathcal{I}_{\rm w} = \sum_{\alpha,l} n_\alpha |\psi_\alpha(l)|^4 \qquad \bar{\mathcal{I}}_{\rm w}$$



$W = 5J$ and $\Delta = 14J$ large disorder large interaction
$W = 10J$ and $\Delta = 0.1J$ large disorder small interaction
$W = 0.1J$ and $\Delta = 0.1J$ small disorder
$W = 0.1J$ and $\Delta = 10J$ small disorder

All the natural orbitals can be exponentially localized!

X. Xu, C. Guo, DP, Phys. Rev B Rapid (2018)

Plan of the presentation

1) Perfect spin rectifier

Physical Review Letters (2018)

V. Balachandran

E. Pereira

G. Benenti

G. Casati

+ D.P.

2) Interplay between disorder, strong interactions and tailored dissipation

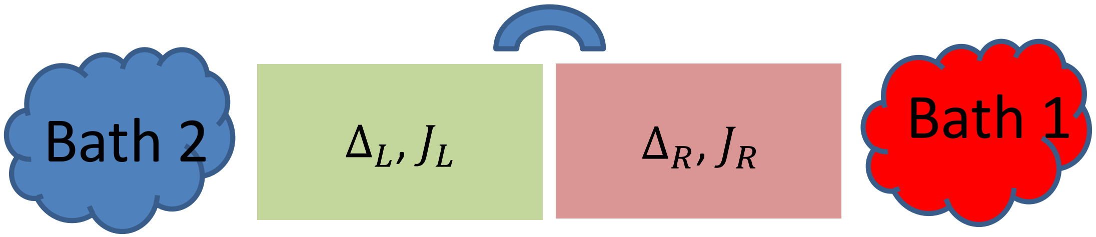
Physical Review B, 97, 140201(R) (2018)

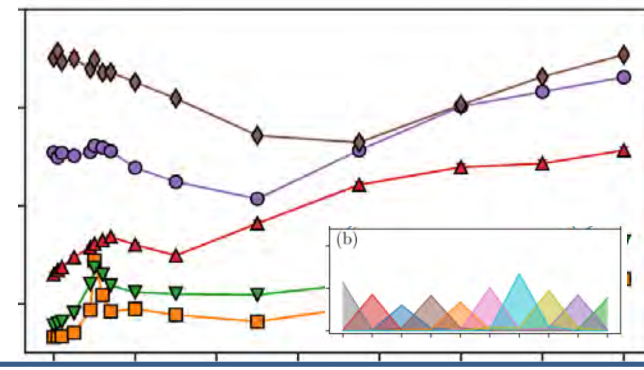
X. Xu

C. Guo

+ D.P.

Conclusions and Outlook

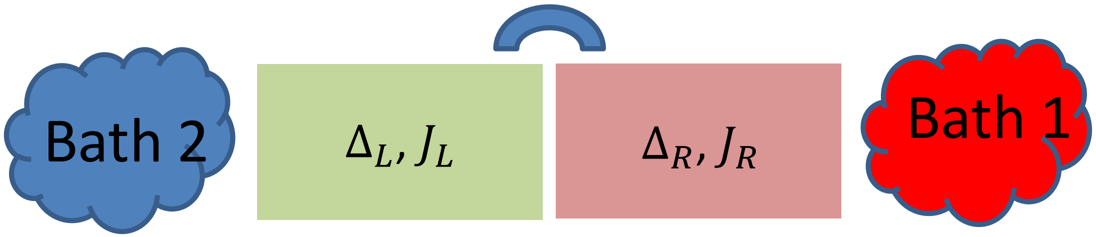


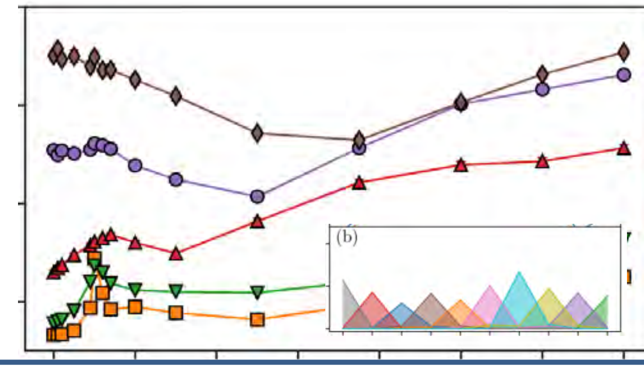


CONCLUSIONS and **OUTLOOK**

- We have shown how a spin current diode would work thanks to **interactions**. The **rectification** can be very strong and fairly robust.
  - Different interactions?
  - Thermal baths?
  - …

- We have studied the localization properties of a **disordered many body** quantum system in the presence of a **dissipator** which reduces the effects of disorder. For large enough disorder it is possible to have some sort of localization in the disordered potential.
  - Full mapping of the phase diagram
  - Interplay with a periodic driving
  - Transients?
  - …





Principal Investigator
Dario Poletti

PostDocs
Mikel Palmero
Vinitha Balachandran

PhD Students
Guo Chu
Ryan Tan
Tianqi Chen
Lee Kang Hao

Research Assistants
Xu Xiansong
Kenny Choo

Undergraduate Researchers
Wu Zheyu
Reuben Wang
Bo Xing

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

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