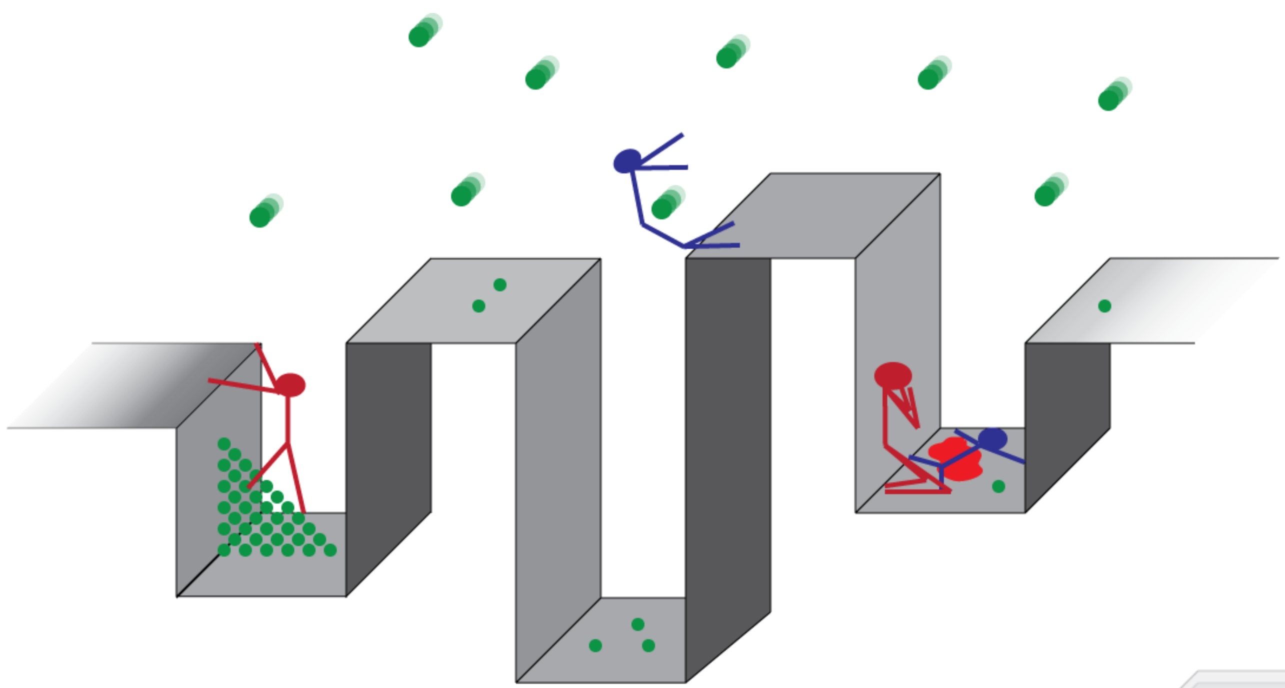
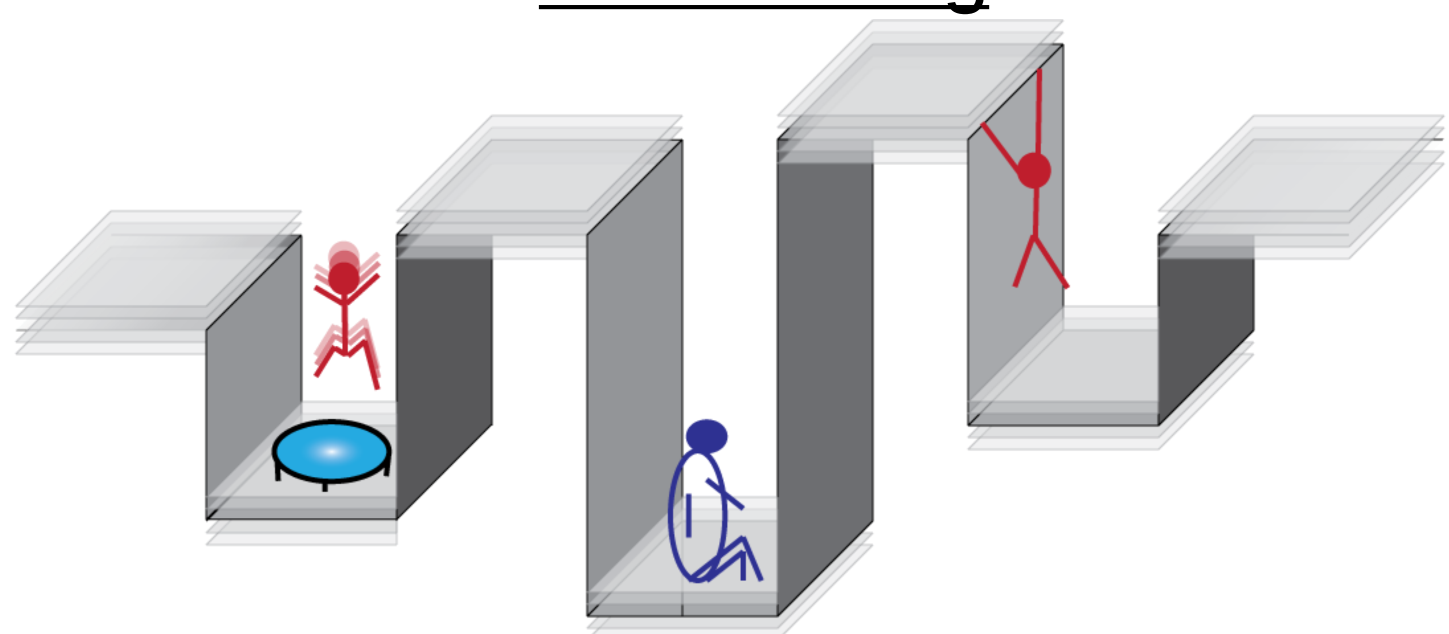
Probing MBL with ultracold atoms – Part 2

Henrik Lüschen



2.1 Photon Scattering

2.2 Shaking



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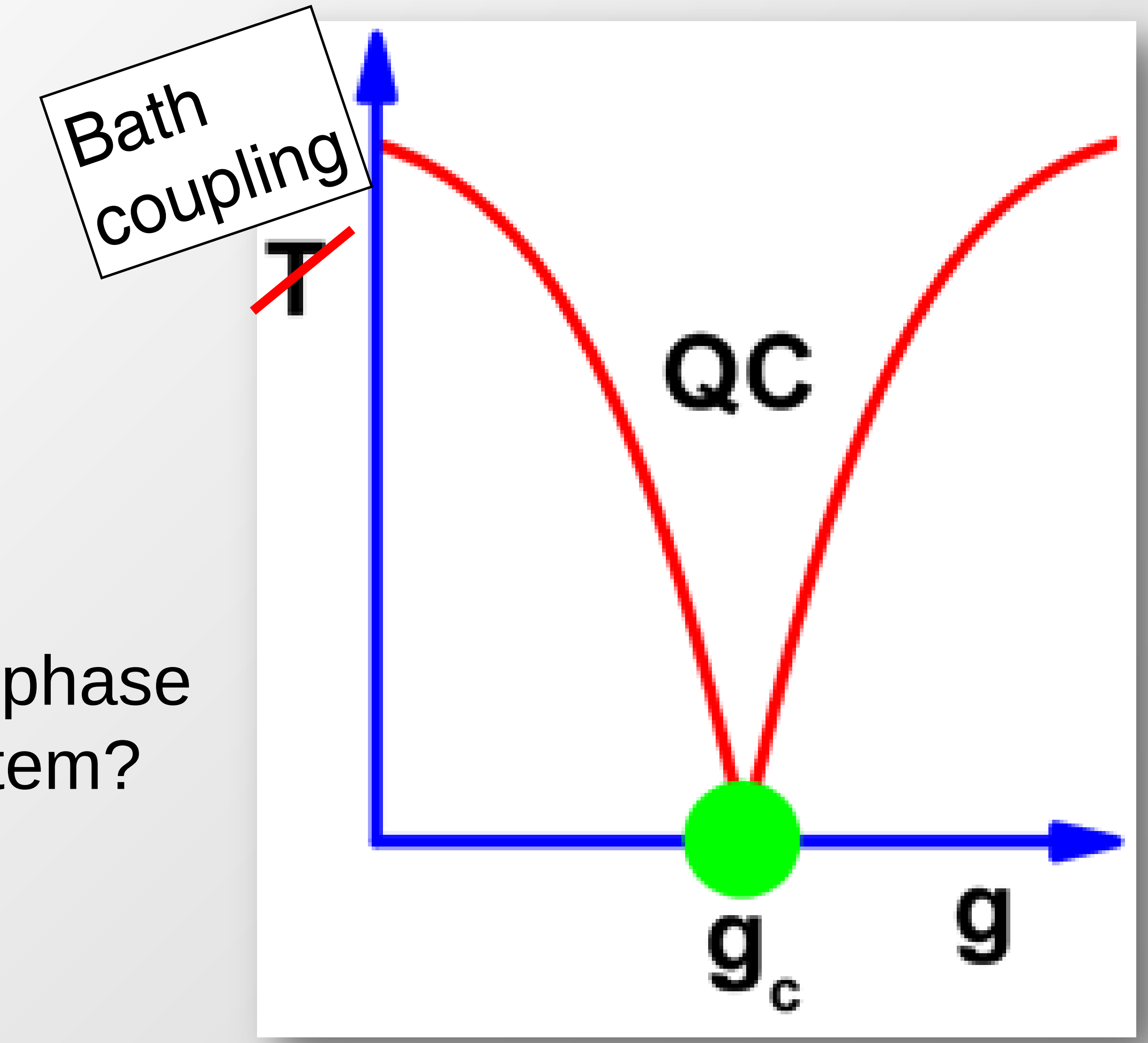
Motivation

- MBL only exists in perfectly isolated systems:
- Coupling an MBL system to a bath restores ergodicity



Q: How does the proximity of the MBL phase affect the dynamics of the coupled system?

- Photon scattering as infinite bandwidth, Markovian bath
  - Scattering rate $\Gamma \sim \frac{I}{\delta^2}$ -> Little light scattering from lattices
  - Use extra scattering beam with $\delta \sim 1.2$GHz

Scattering Effects

1. Localization Events:

– Re-emitted photon entangles system with environment

– Trace out environment -> obtain Lindblad equation

$$\dot{\rho}(t) = -i\,[H, \rho(t)] + \gamma \sum_{l=1}^{N} \left[n_l \rho(t) n_l - \frac{1}{2} \{ n_l, \rho(t) \} \right] \; ^{*}$$

➡ Effective number operator measurement

2. Particle Loss:

– Excited atomic state sees different lattice potential

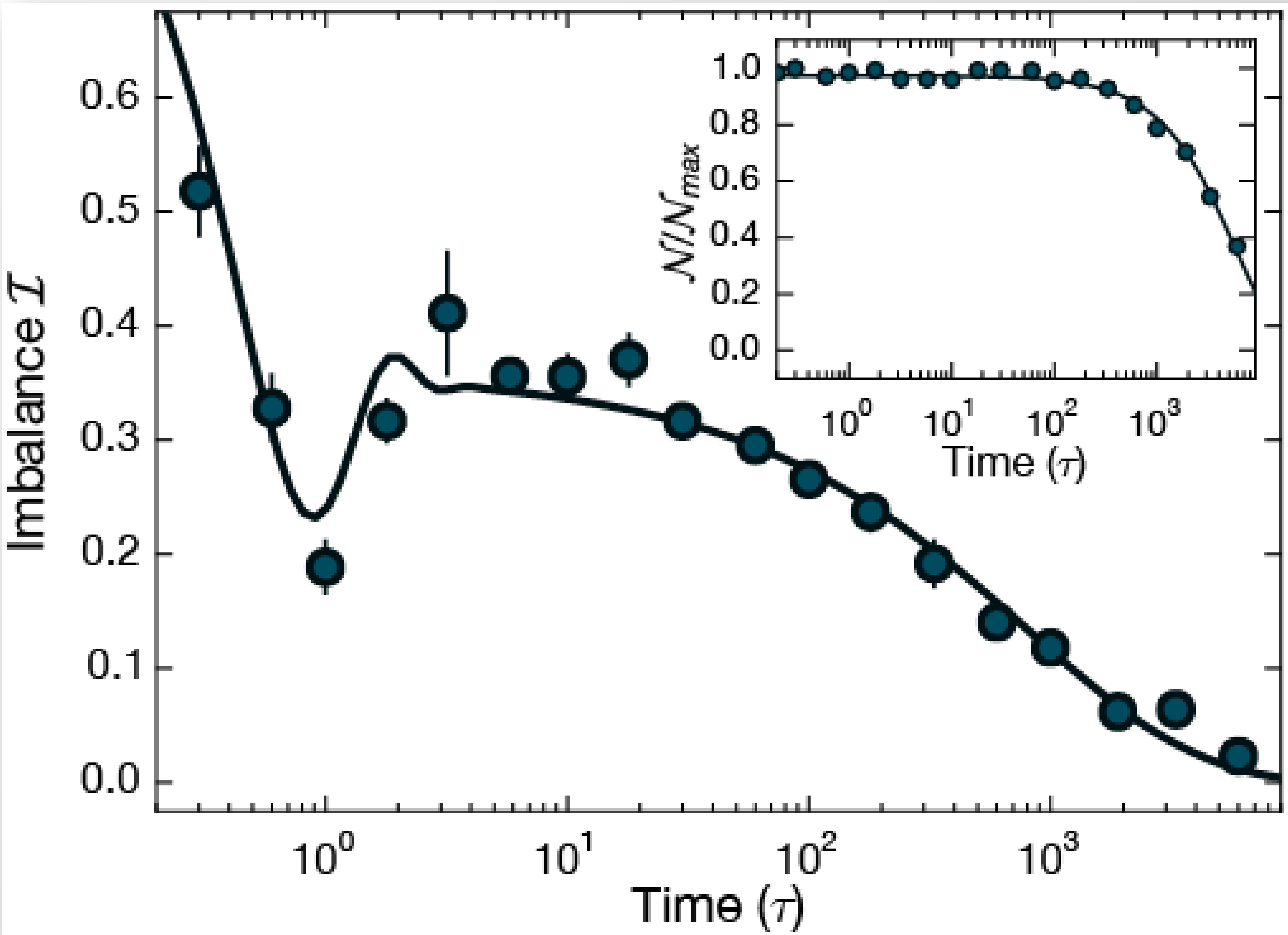
– Acceleration of atoms to higher bands

- In out case: approx 50/50 chance for each process and scattering preserves spin
- Weak scattering limit (~1 event / particle / 100 tunneling times)

Sarkar, arXiv: 1405.7336
Levi, arXiv: 1510:04634

Time Traces

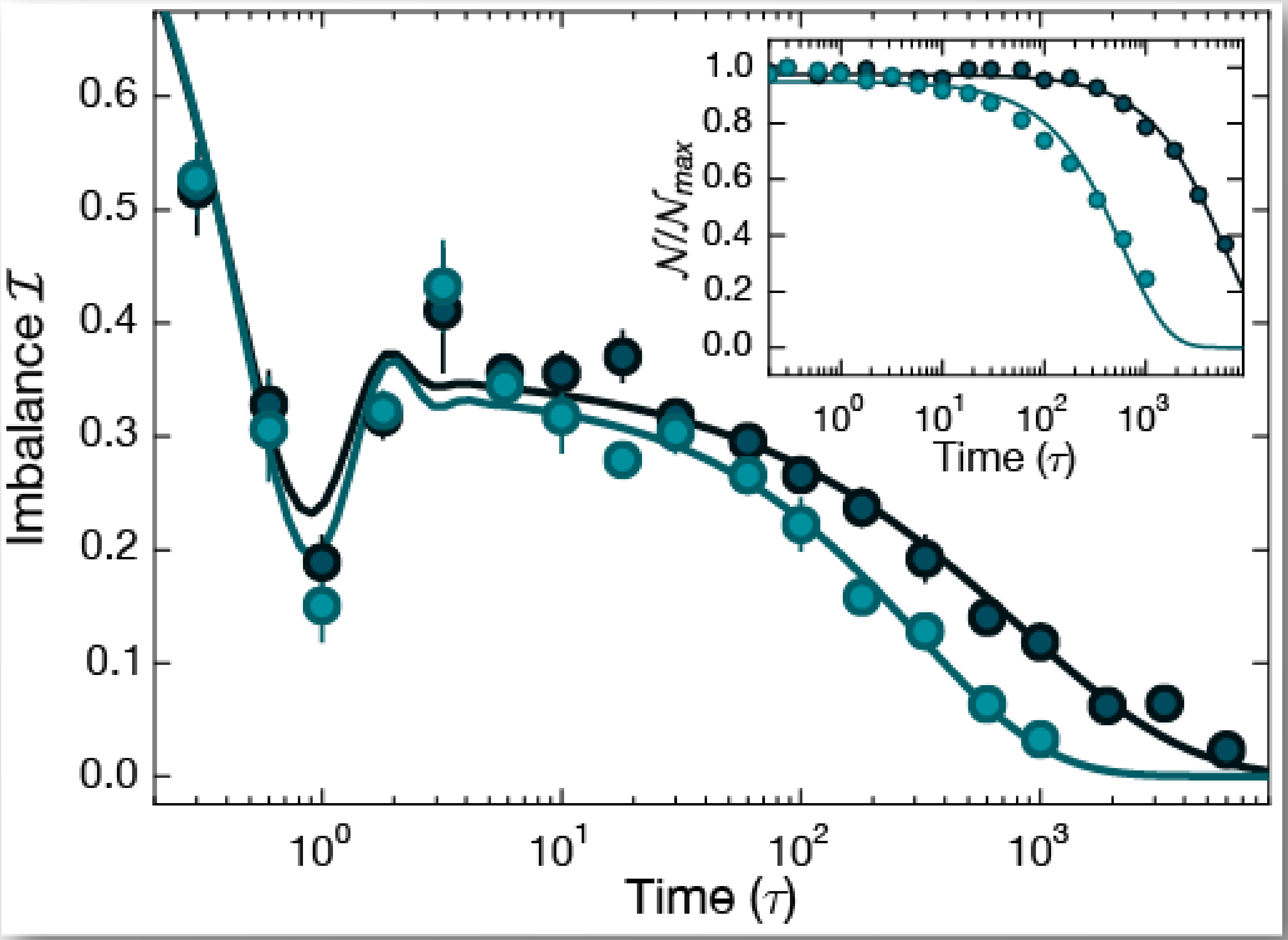
Non-interacting, Δ/J = 4



I_{scatt} = 0.00V

Time Traces

Non-interacting, Δ/J = 4

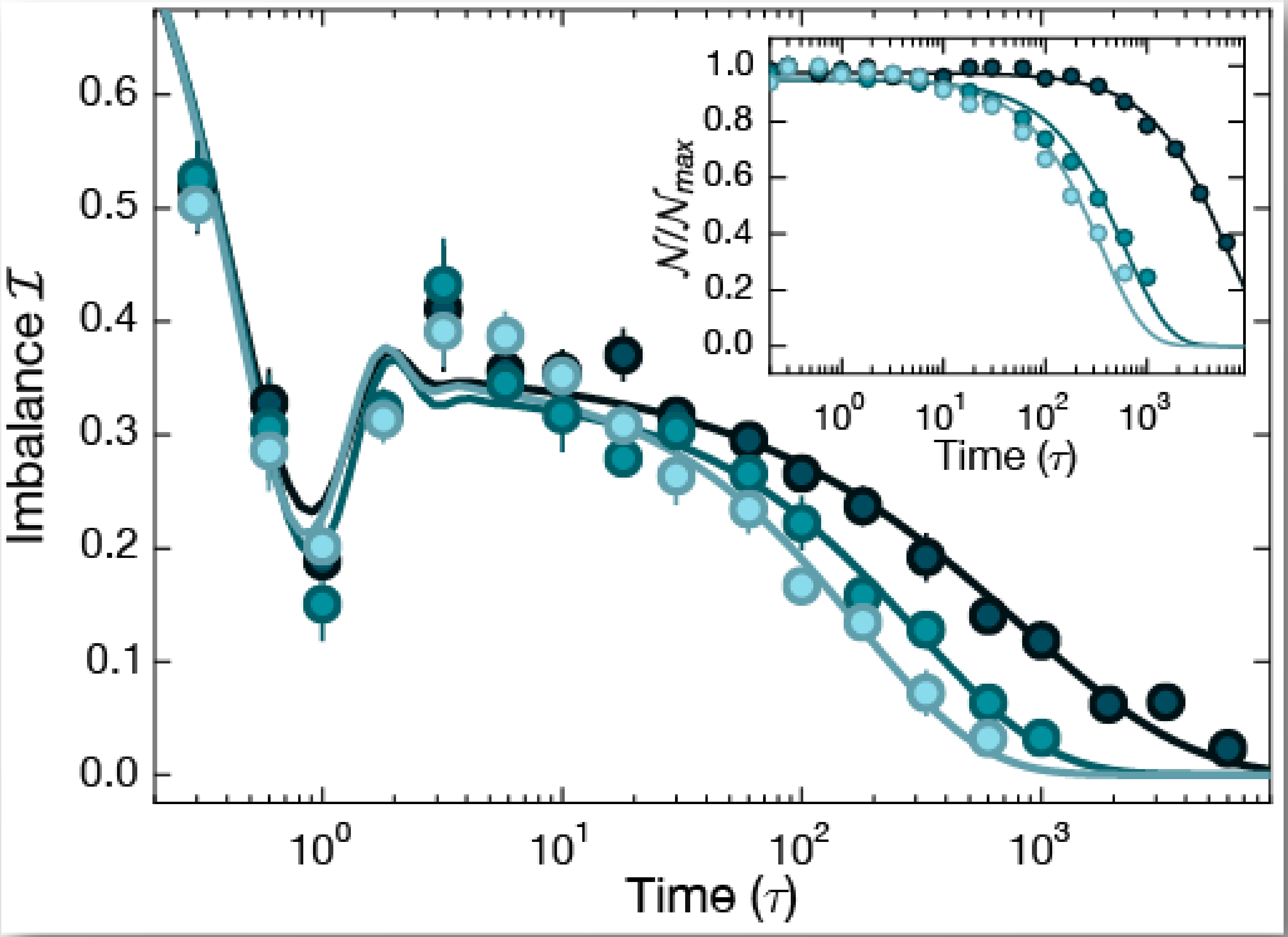


I_{scatt} = 0.00V

I_{scatt} = 0.15V

Time Traces

Non-interacting, Δ/J = 4



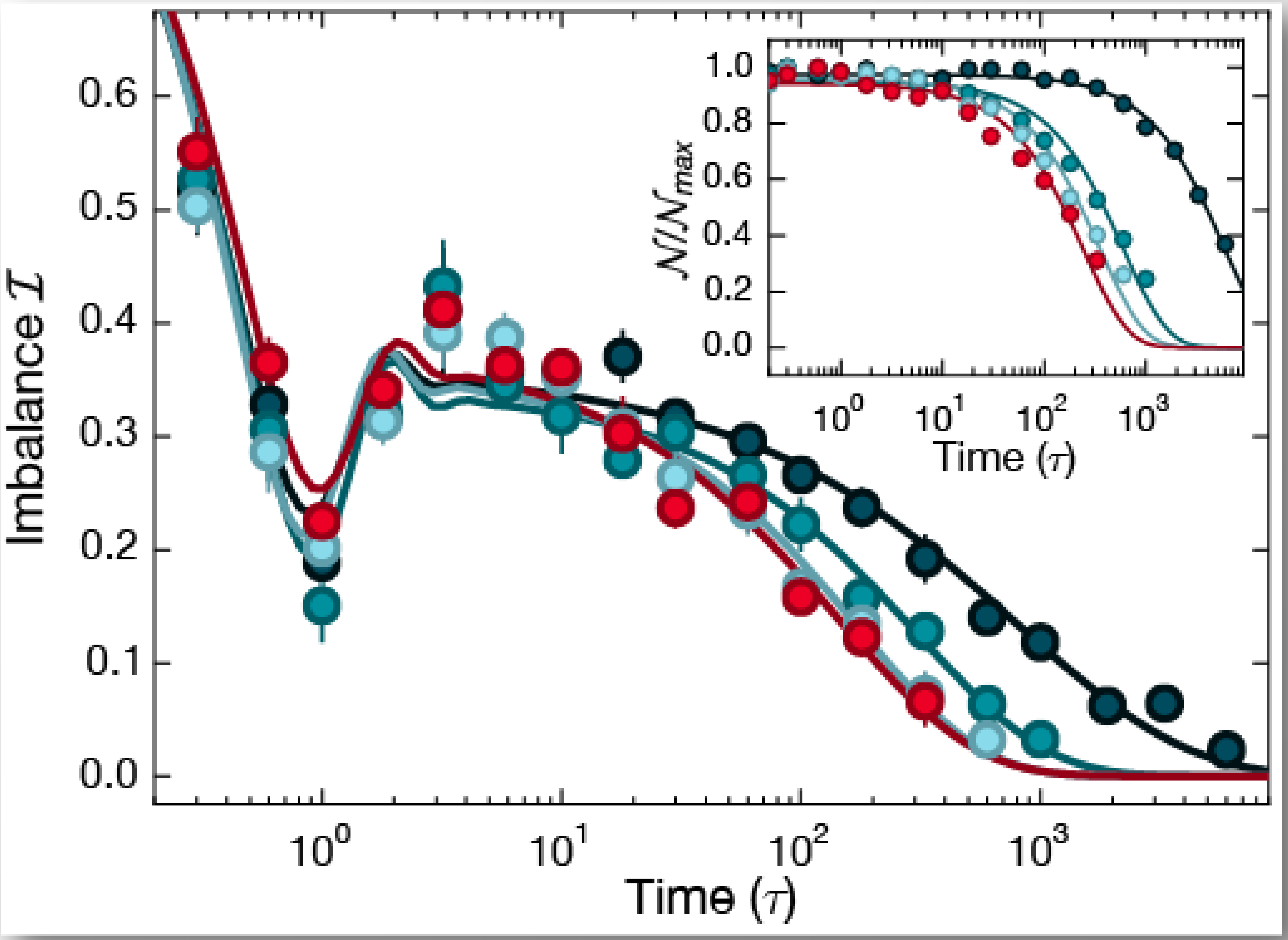
I_{scatt} = 0.00V

I_{scatt} = 0.15V

I_{scatt} = 0.30V

Time Traces

Non-interacting, Δ/J = 4



I_{scatt} = 0.00V

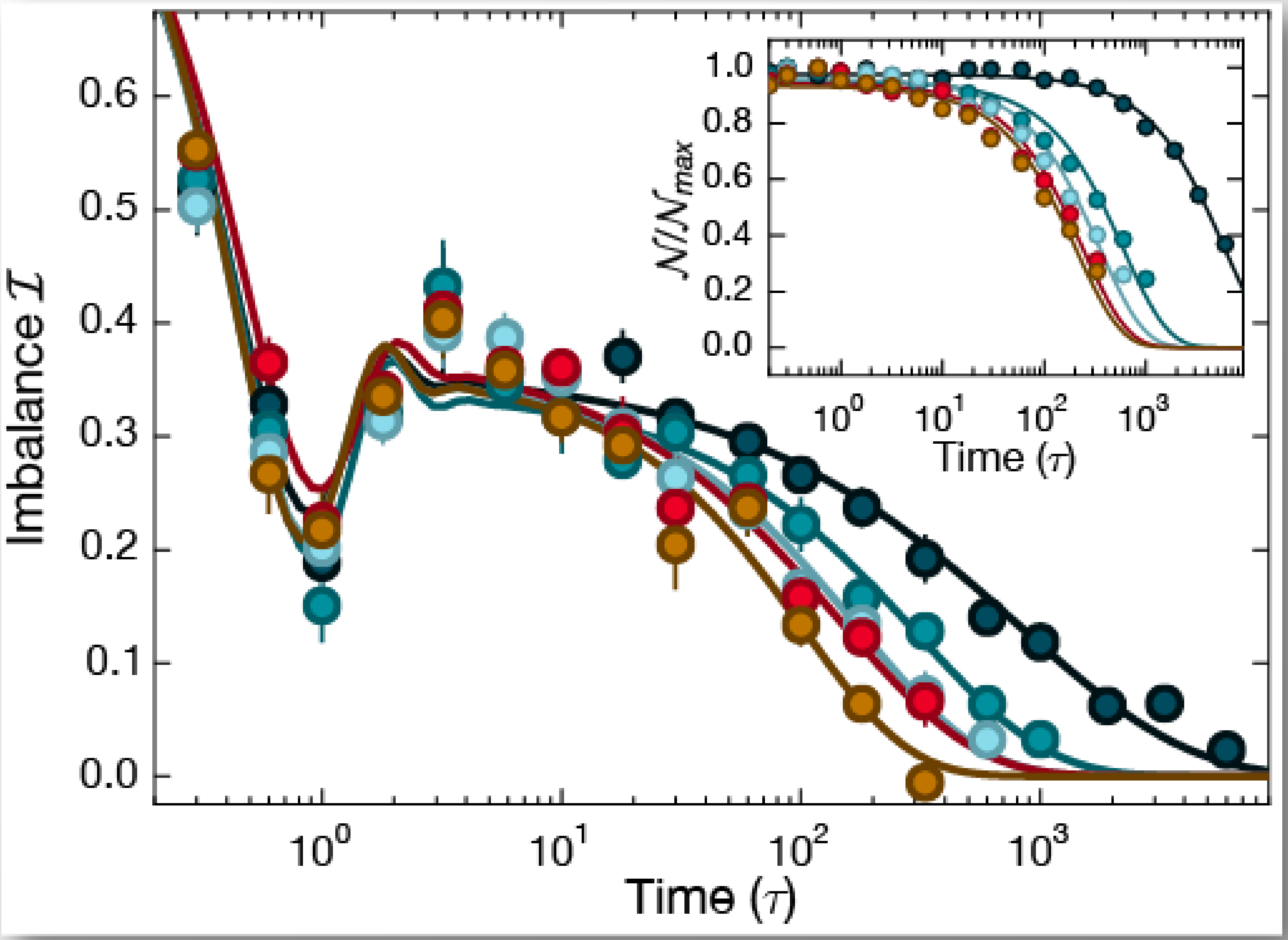
I_{scatt} = 0.15V

I_{scatt} = 0.30V

I_{scatt} = 0.45V

Time Traces

Non-interacting, Δ/J = 4



I_{scatt} = 0.00V

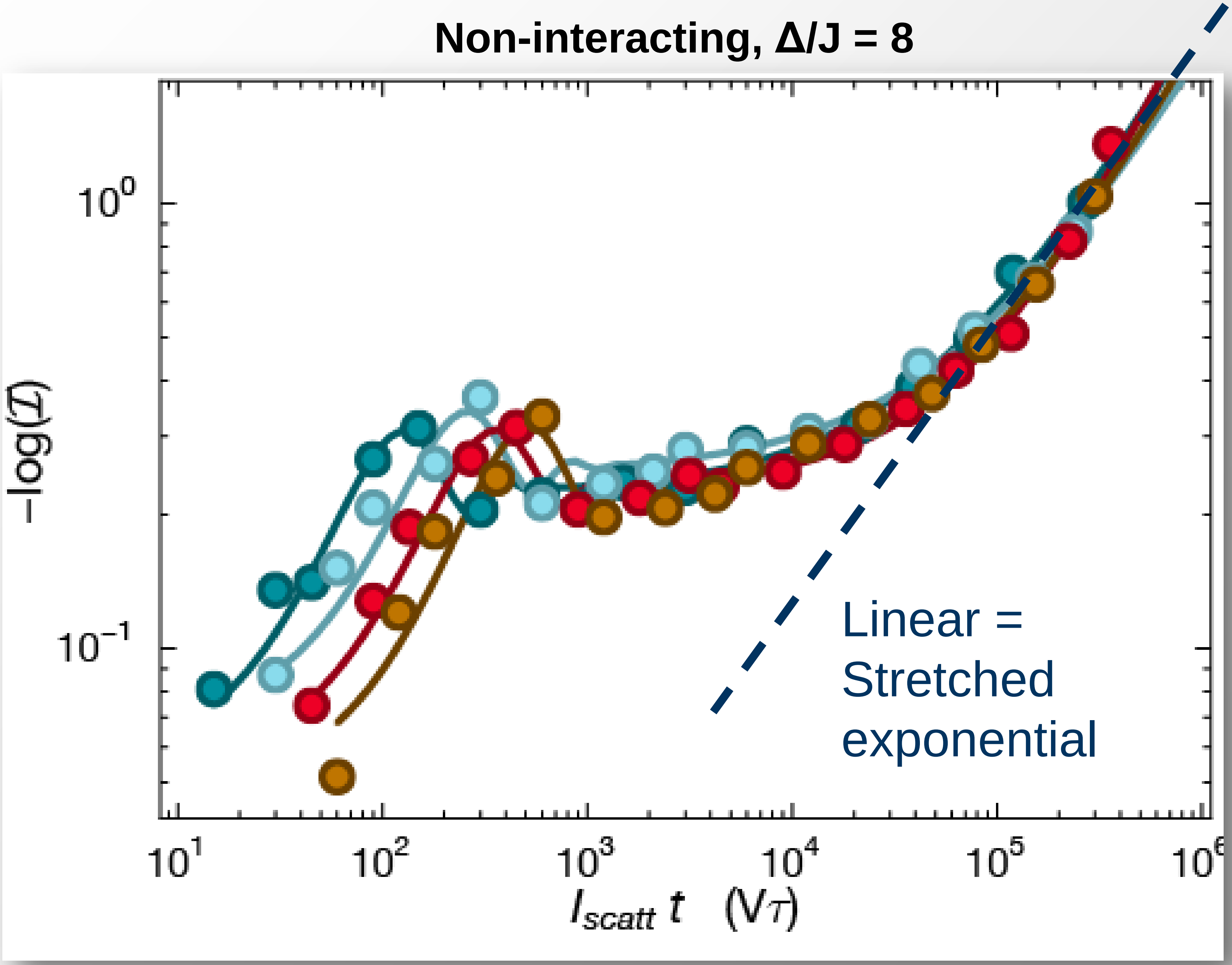
I_{scatt} = 0.15V

I_{scatt} = 0.30V

I_{scatt} = 0.45V

I_{scatt} = 0.60V

Time traces

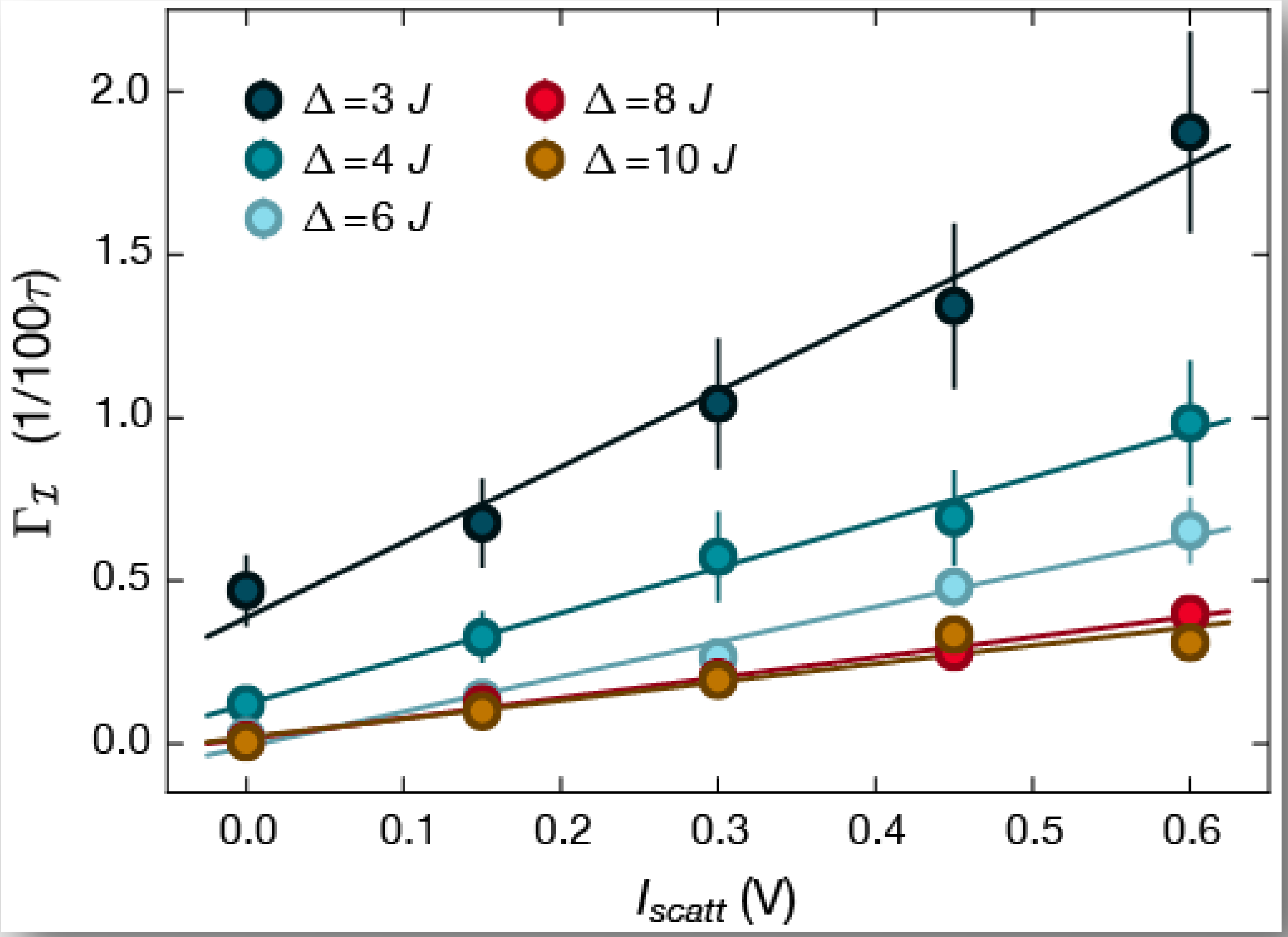


➡ Universal behaviour in $I_{scatt}t$

Extracting Photon Scattering effects

- Fit linear behaviour:
  - Slope: Effect of Photon scattering
  - Offset: Other effects, e.g. lattice photons, 2D-coupling, heating

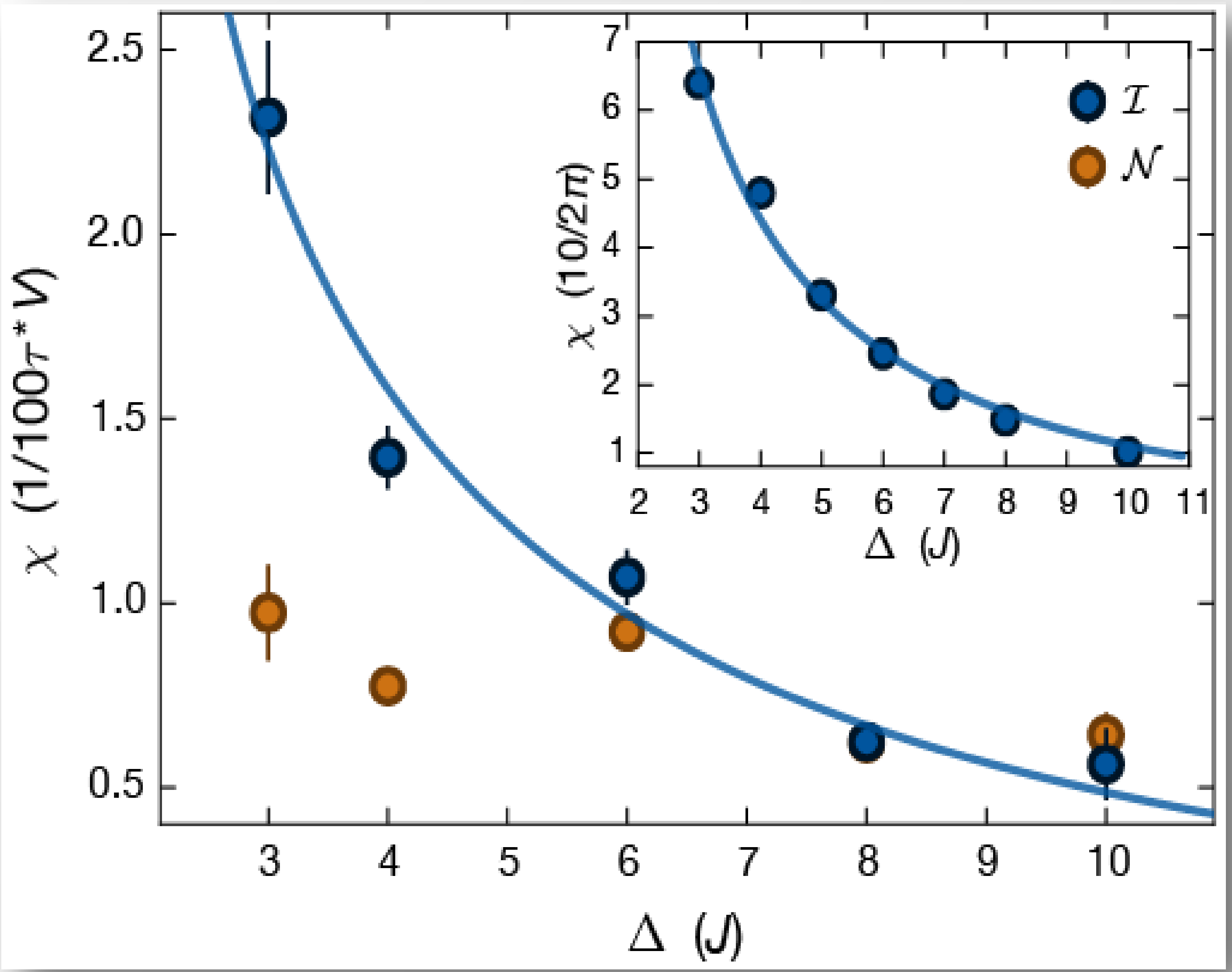
Non-interacting



➡ Define Susceptibility χ as the slope: $\chi = \frac{d\Gamma}{dI_{scatt}}$

Non-interacting Susceptibility

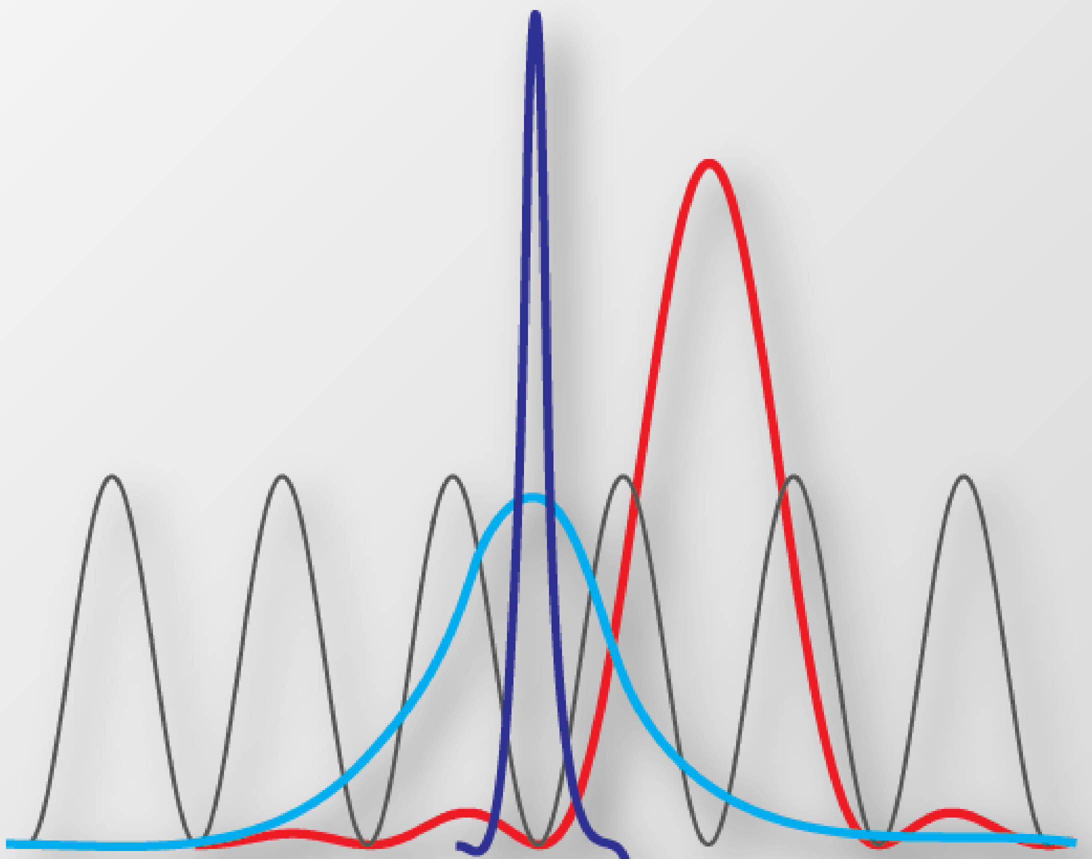
Non-interacting, Inset: Theory



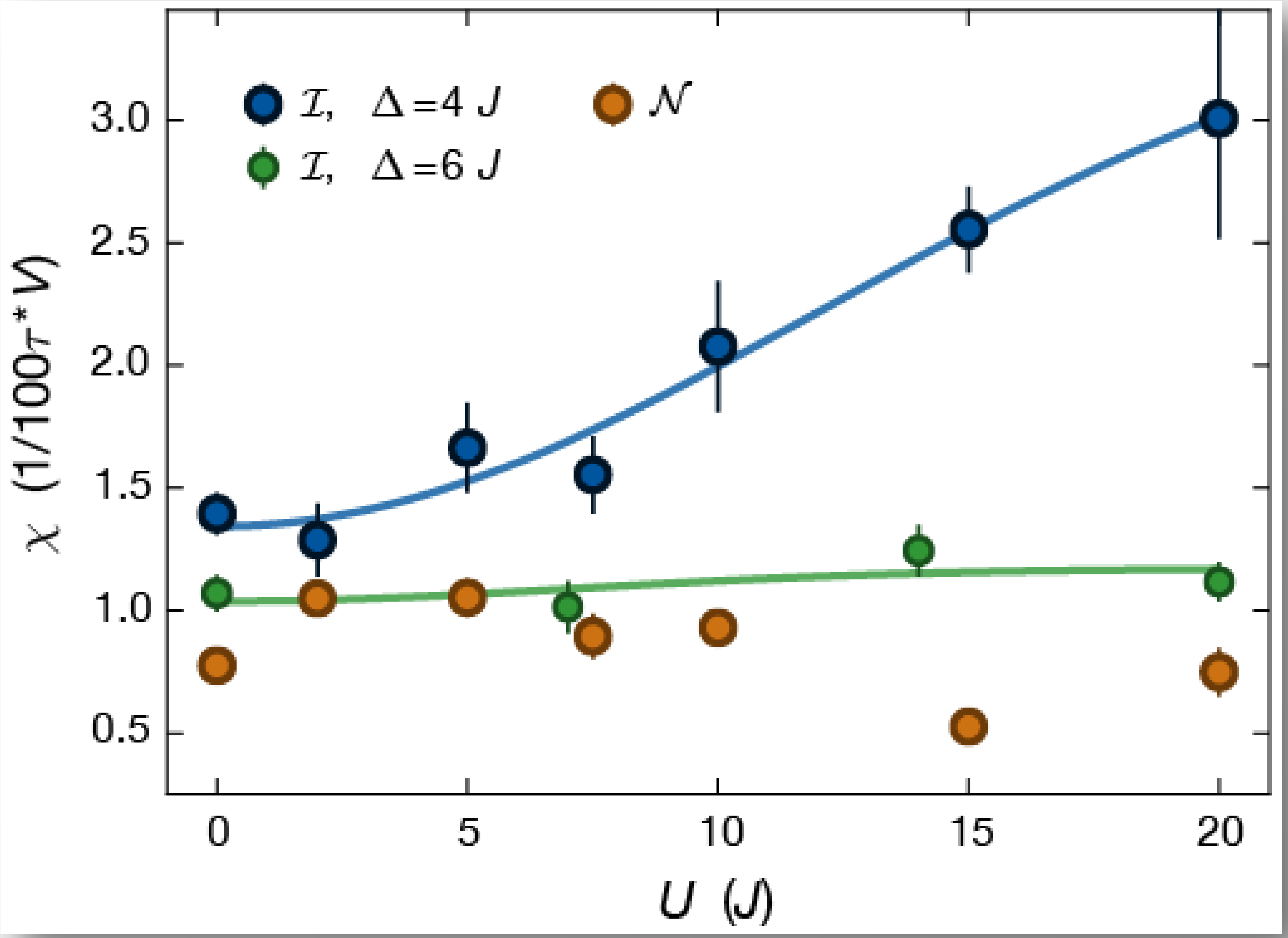
- Strongly increasing χ when approaching the phase transition.
- Atom numbers are unaffected by Δ
- Qualitatively similar behaviour bwetween theory and experiment

Non-interacting: Interpretation

- Non-interacting: Particle loss has no effect
- Weak scattering limit: System is typically diagonal in local integrals of motion
- Scattering re-localizes particles to Wannier states which then relax again



Interacting Susceptibility



- No theory yet!
- Particle loss matters!
  - Not clear whether interaction effect due to particle loss or localizations
- Interaction effect only visible close to the transition

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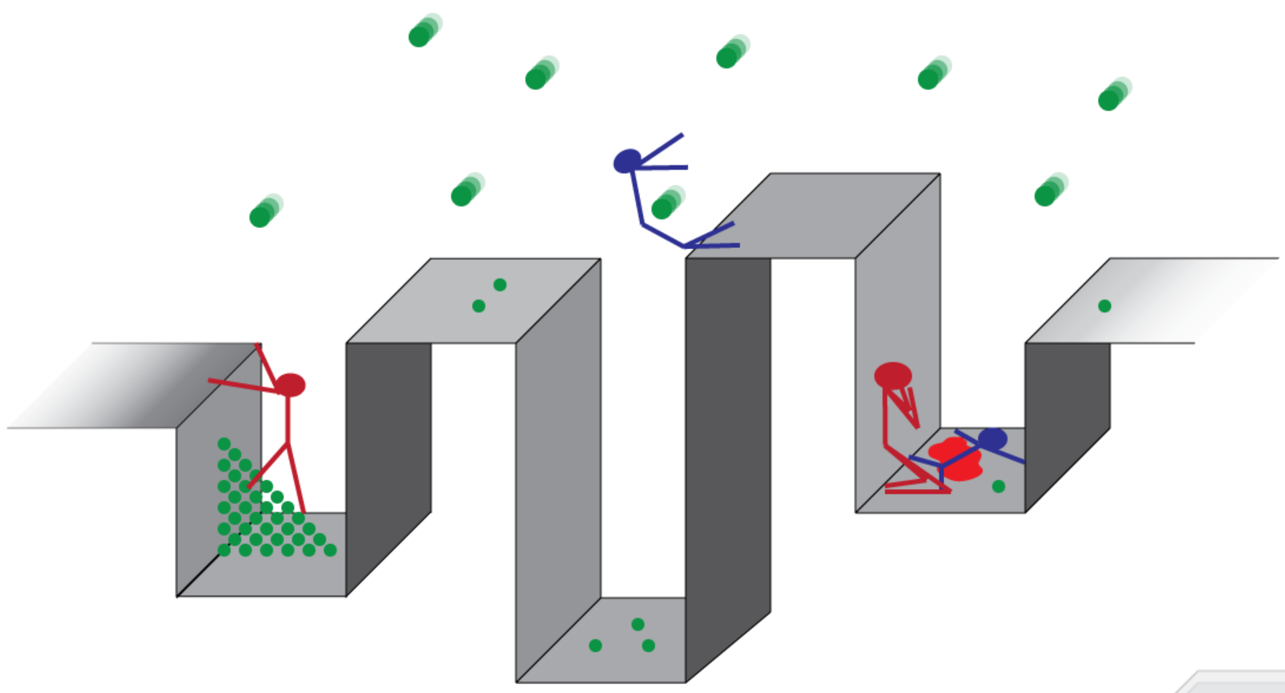
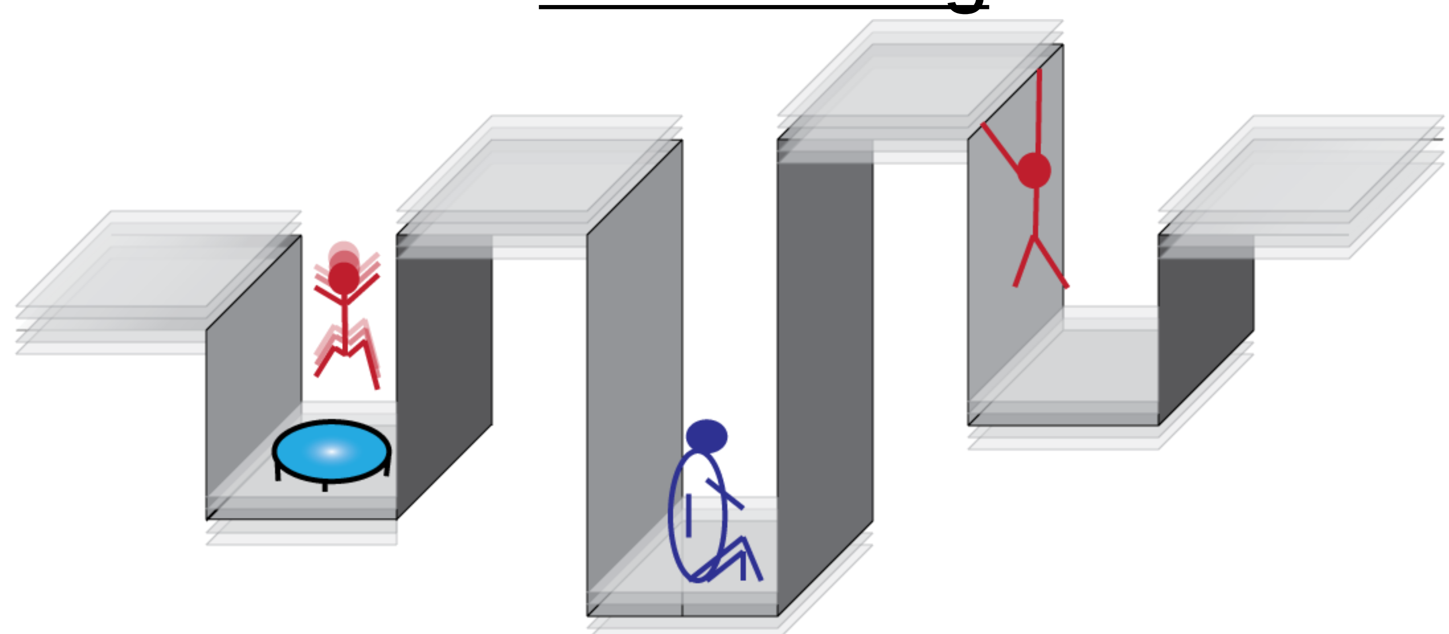


2.1 Photon Scattering

2.2 Shaking



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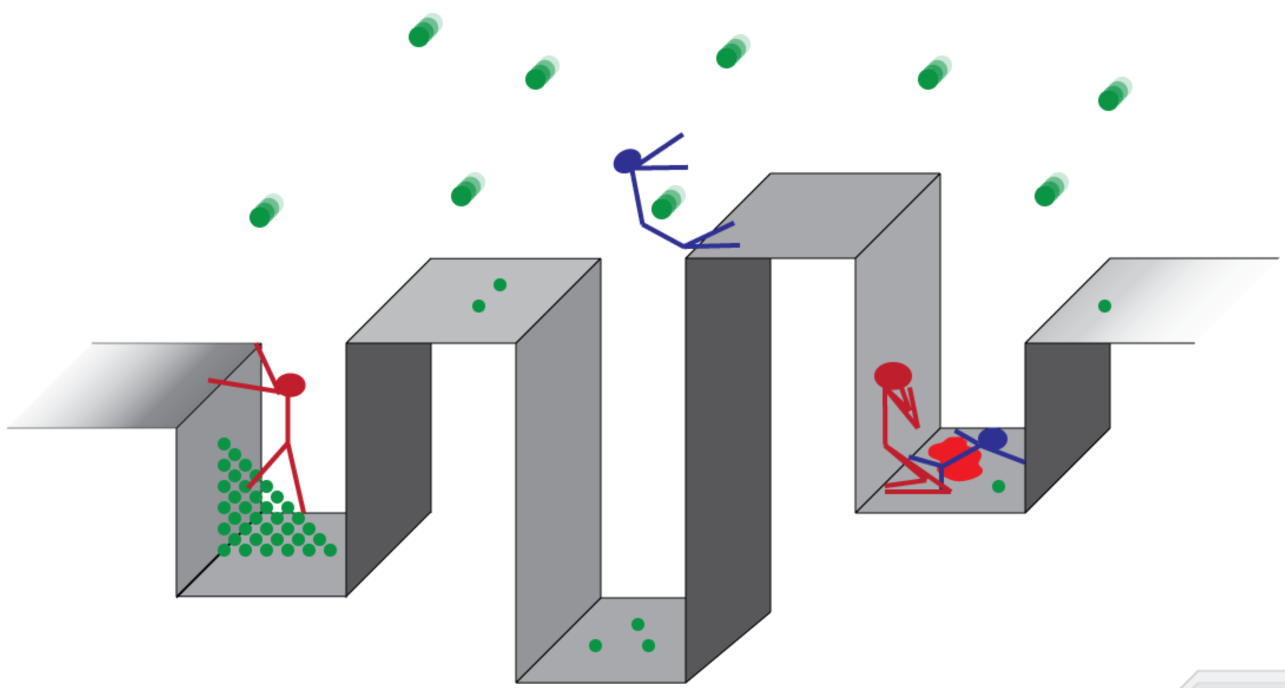

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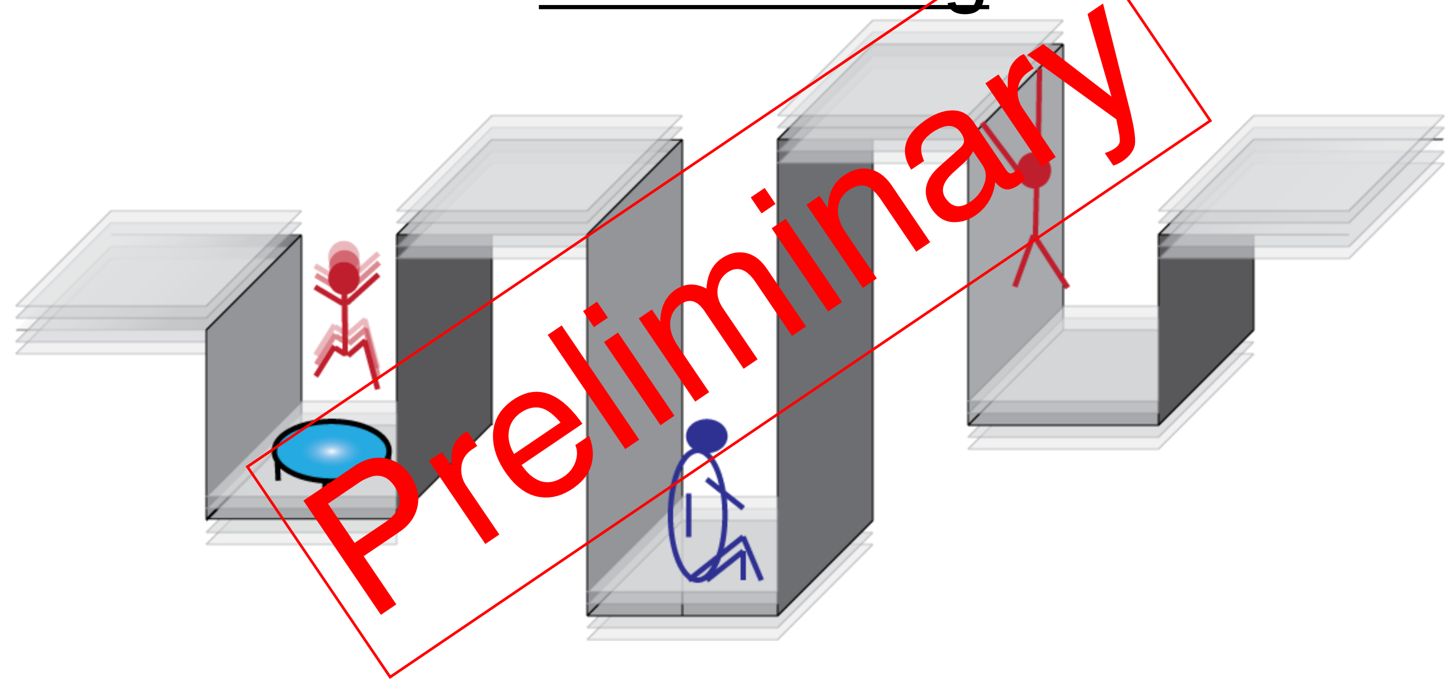

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Setup and Hamiltonian

- Shake amplitude of disorder lattice

$$H(t) = H_{MBL} + V(t)$$

$$H_{MBL} = -J \sum_{l,\sigma} (c_{l+1,\sigma}{}^{+} c_{l,\sigma} + h.c.) + \Delta \sum_{l,\sigma} \cos(2\pi\beta l + \varphi)\, n_{l,\sigma} + U \sum_{l} n_{l,\uparrow} n_{l,\downarrow}$$

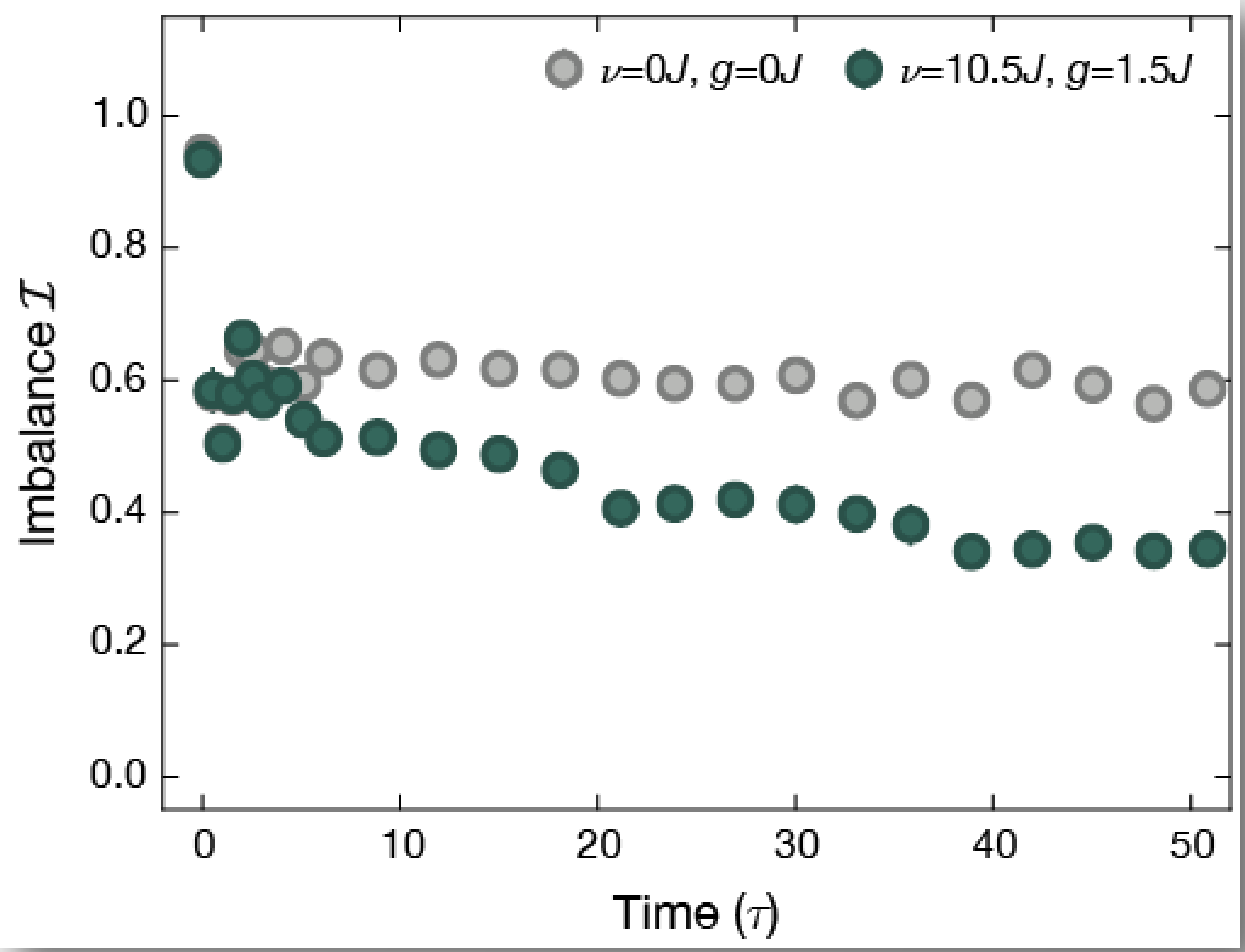
$$V(t) = g \sin(2\pi\nu t) \sum_{l,\sigma} \cos(2\pi\beta l + \varphi)\, n_{l,\sigma}$$

- We observe no increased atom number loss or heating!

- Floquet picture / Coupling to Phonon Bath

Time traces

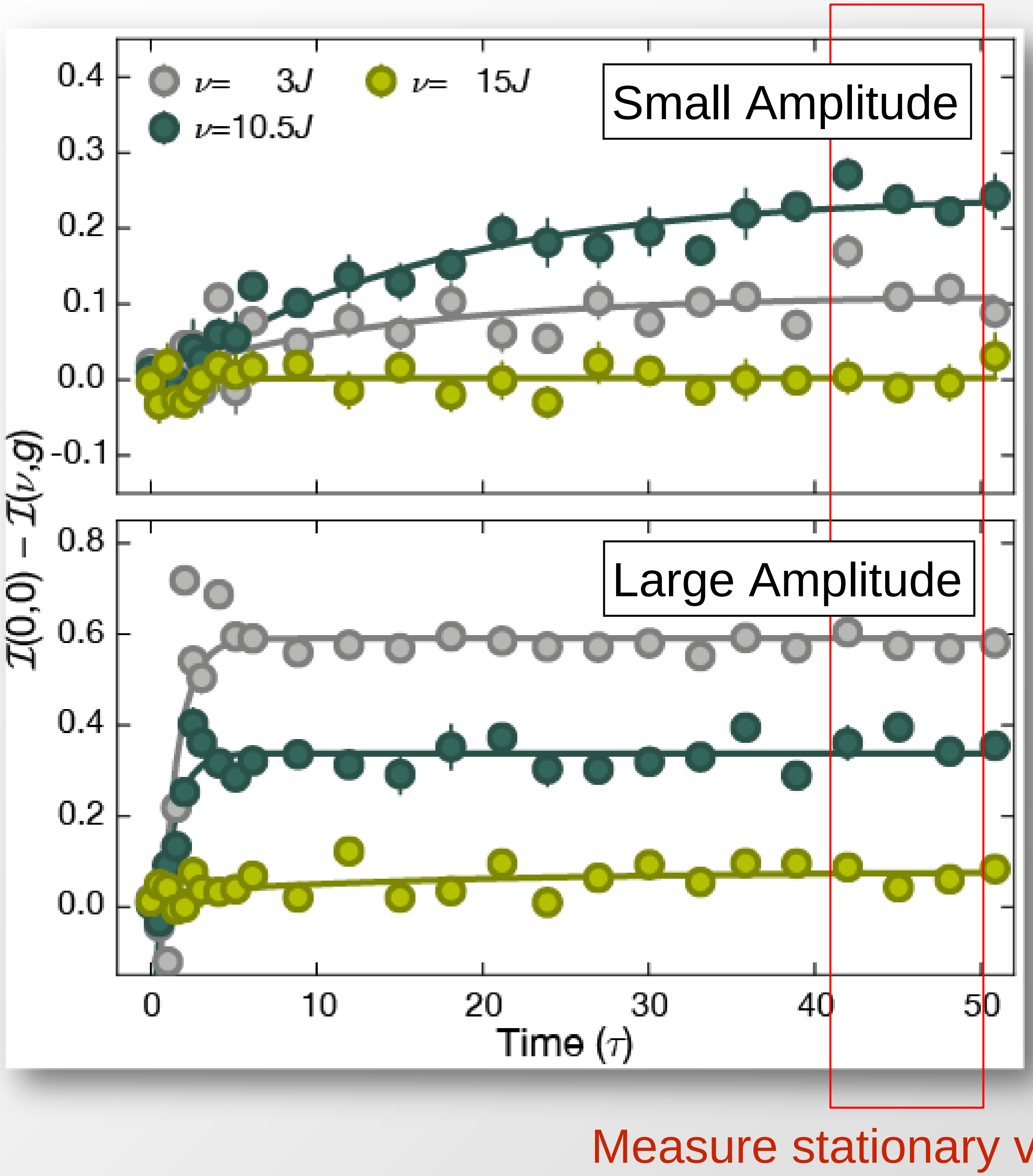
Non-interacting, Δ/J = 7.5



- Additional reduction of Imbalance due to shaking!

Time traces

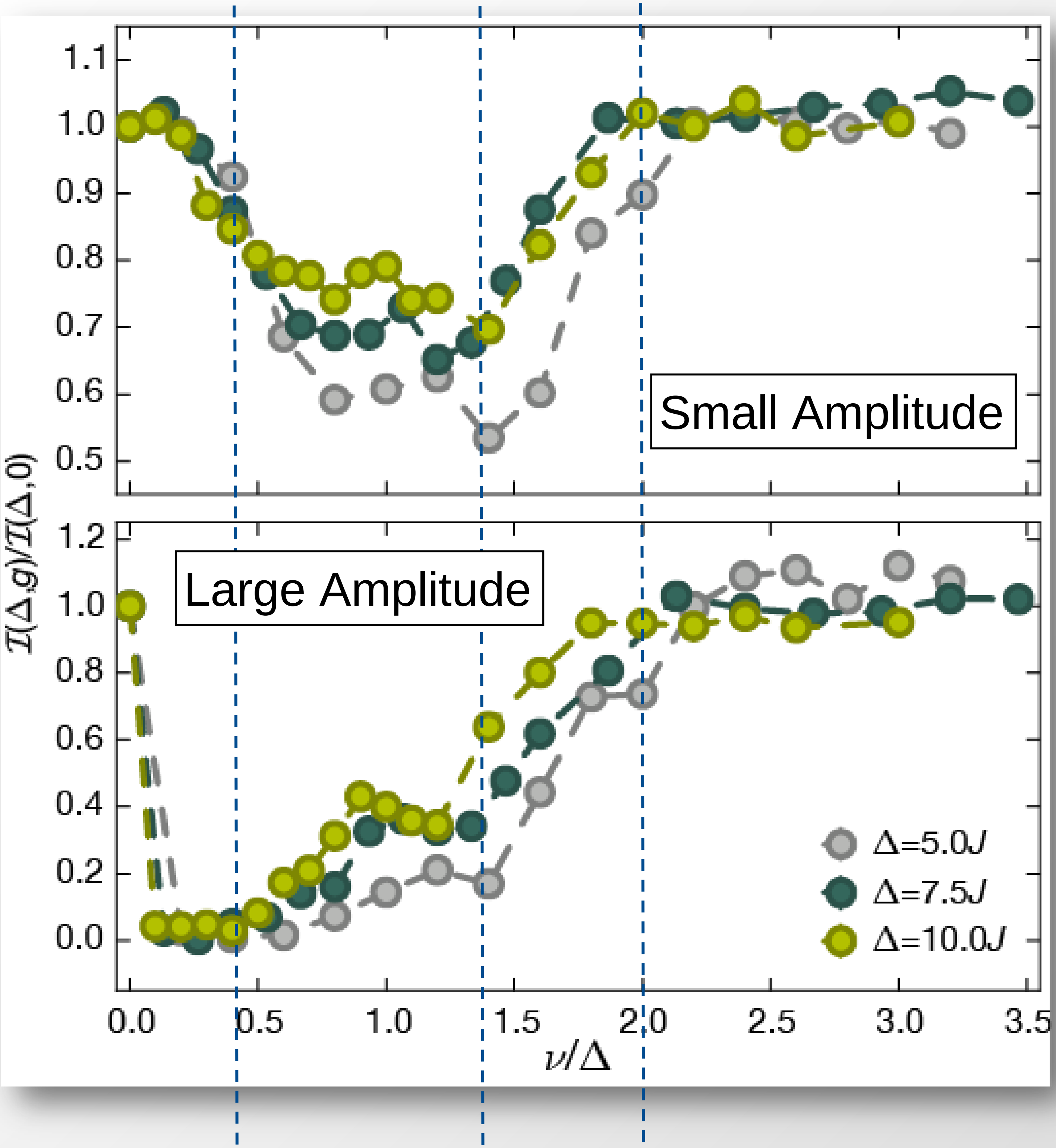
Non-interacting, Δ/J = 7.5



- Saturating behaviour for all time traces -> Shaken Hamiltonian = new stationary Hamiltonian?
- Timescales depend strongly on parameters

Behaviour with frequency

Non-interacting, Δ/J = 7.5

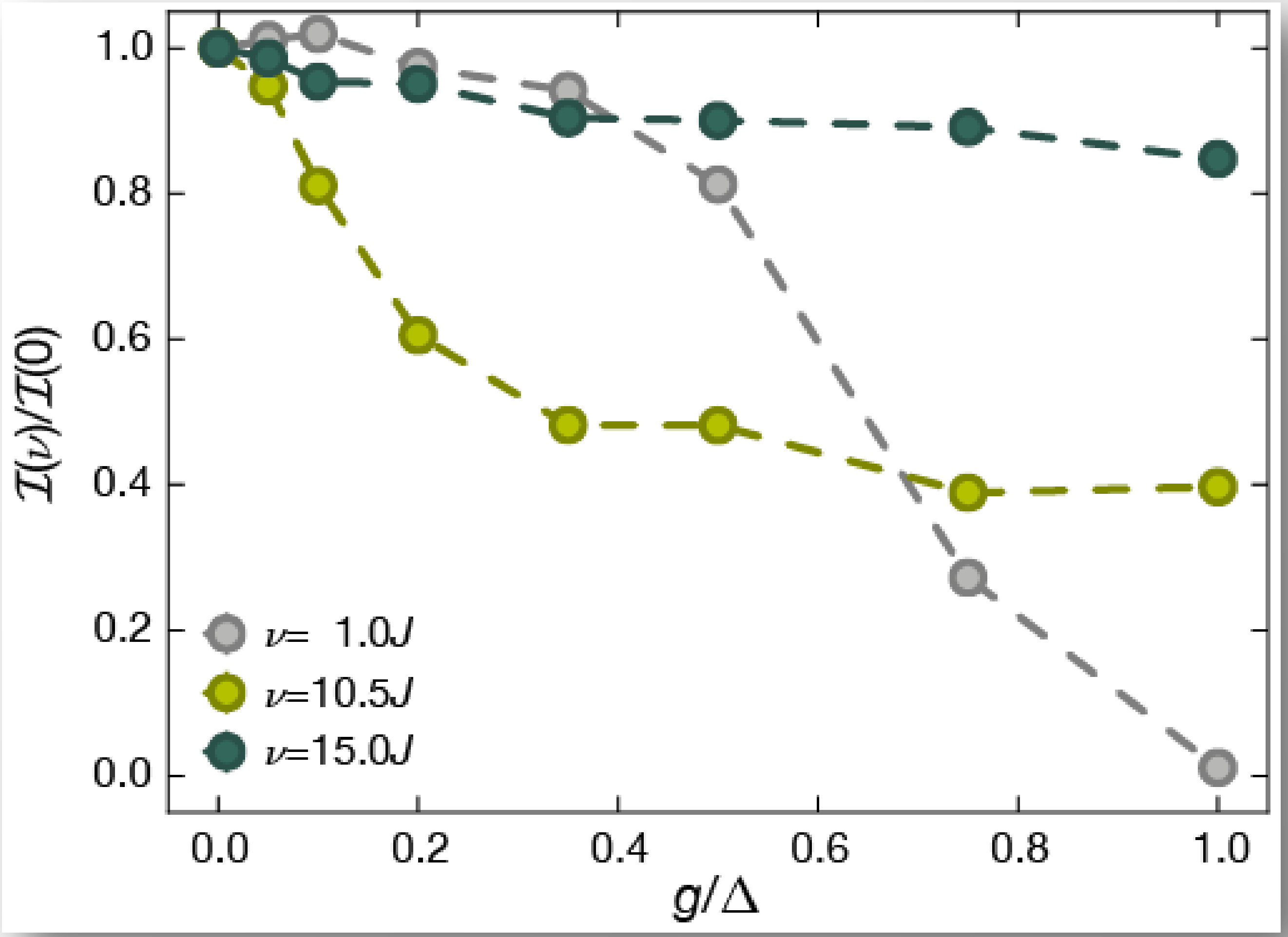


Time traces taken here

- Approximate rescaling of v with Δ
- Small Amplitude absorption resembles nearest neighbour energy difference distribution
- Strong difference between small and large amplitude shaking in low frequency regime

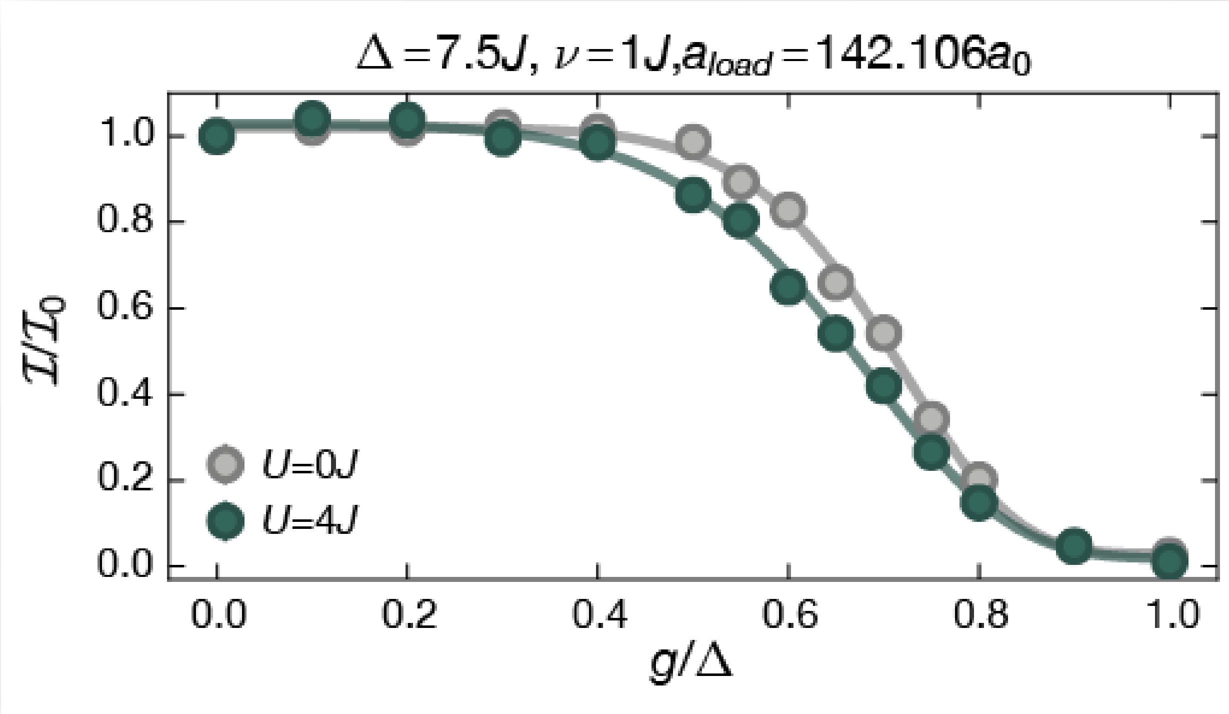
Behaviour with amplitude

Non-interacting, Δ/J = 7.5

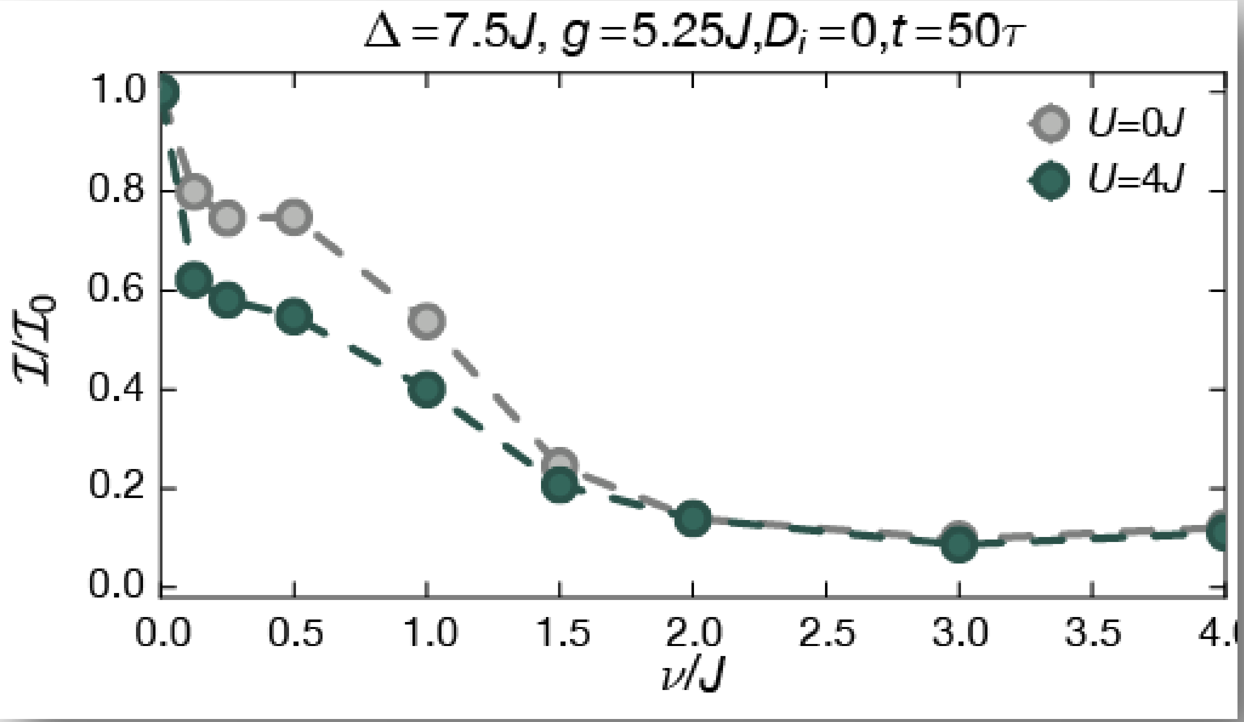


- Very different behaviour between low and medium shaking frequencies
- Adiabatic / non-adiabatic?
- What limits the absorption for intermediate frequencies?

Interaction effects



- Interaction effects only visible at **intermediate amplitudes**



- Interaction effects only visible at **low frequencies**

- Additional interaction effects:
  – Doublons give absorption peaks at U
  – Cannot resolve any small/longterm effects due to backgound decays

Summary

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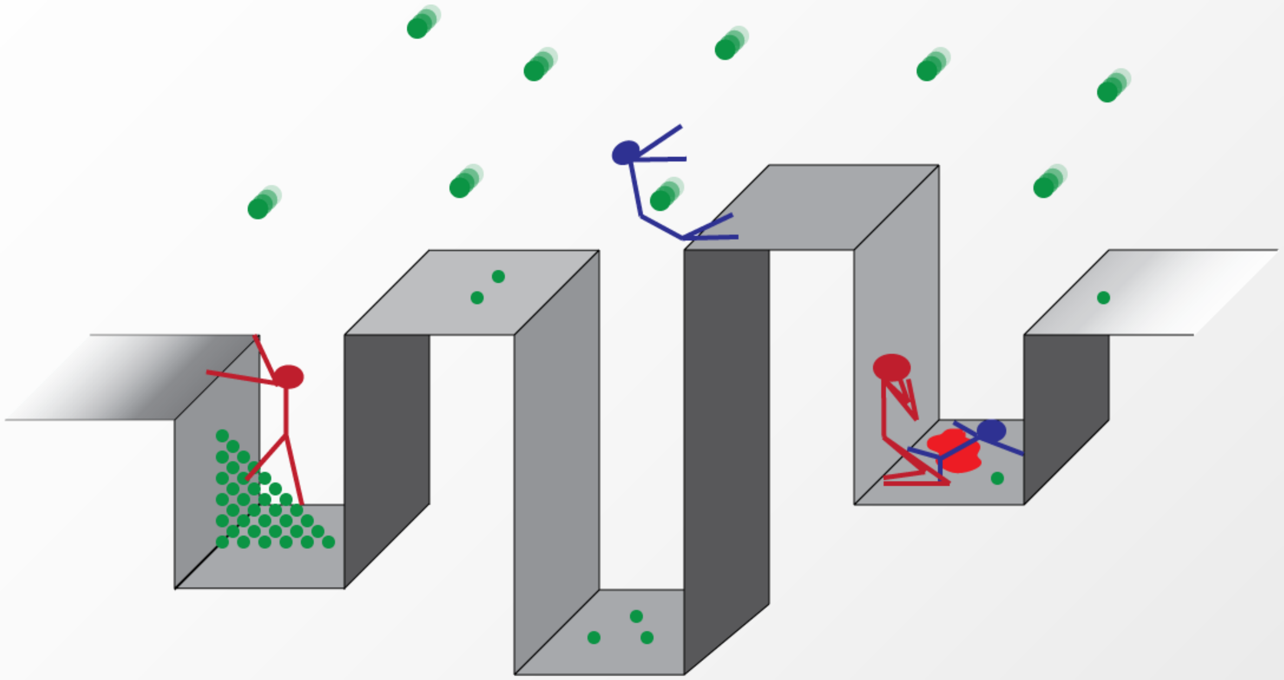
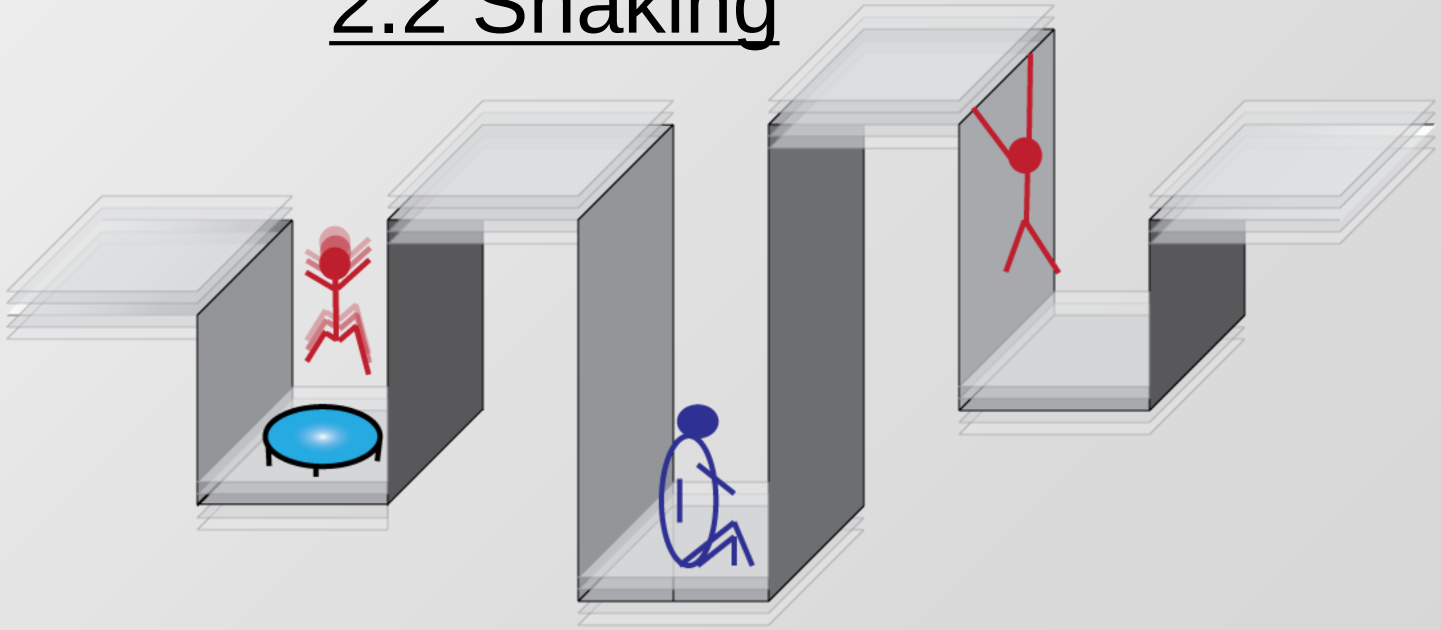


- Increased susceptibility close to transition
- Interaction effect close to transition, but not yet fully understood

2.2 Shaking



- Large parameter space
- Many different regimes
- Many open questions!

Thank you for your attention!