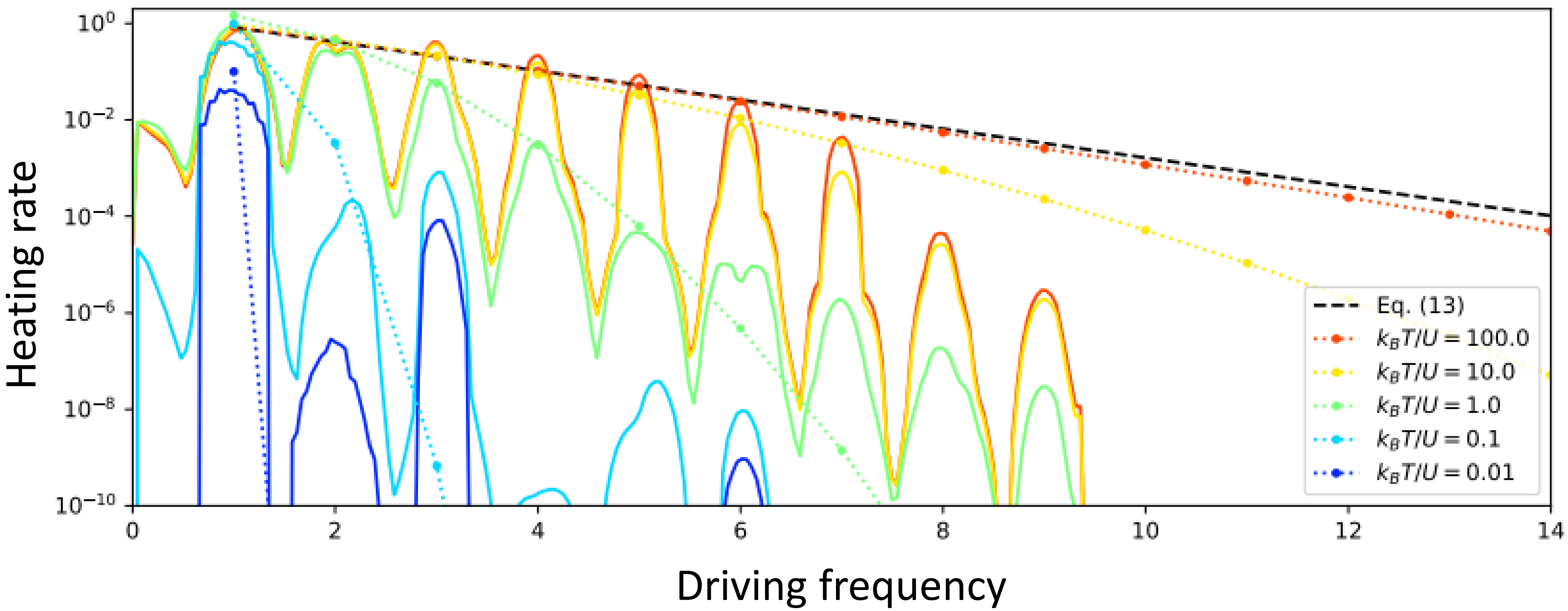
Statistical prethermalization of the Bose-Hubbard model

arXiv:2005.07207



Emanuele Dalla Torre

Bar-Ilan University

Dynamics of many-body quantum research group

Marcello Calvanese Strinati
Leon Bello
Daniel Atzes
Inbar Shani
David Dentelski
Yonatan Saadia
Mor Roses

Atanu Rajak
(→ Kolkata)

Itzhack Dana
Bar-Ilan University

Emanuele Dalla Torre

Bar-Ilan University

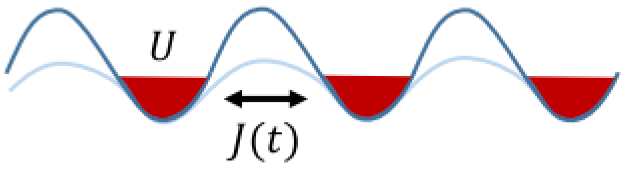
"Periodically driven systems heat up quickly"

- 2^{nd} principle of thermodynamics: periodic drive **give** energy

- Applies to generic many-body systems (chaotic)

Periodically driven Bose-Hubbard model

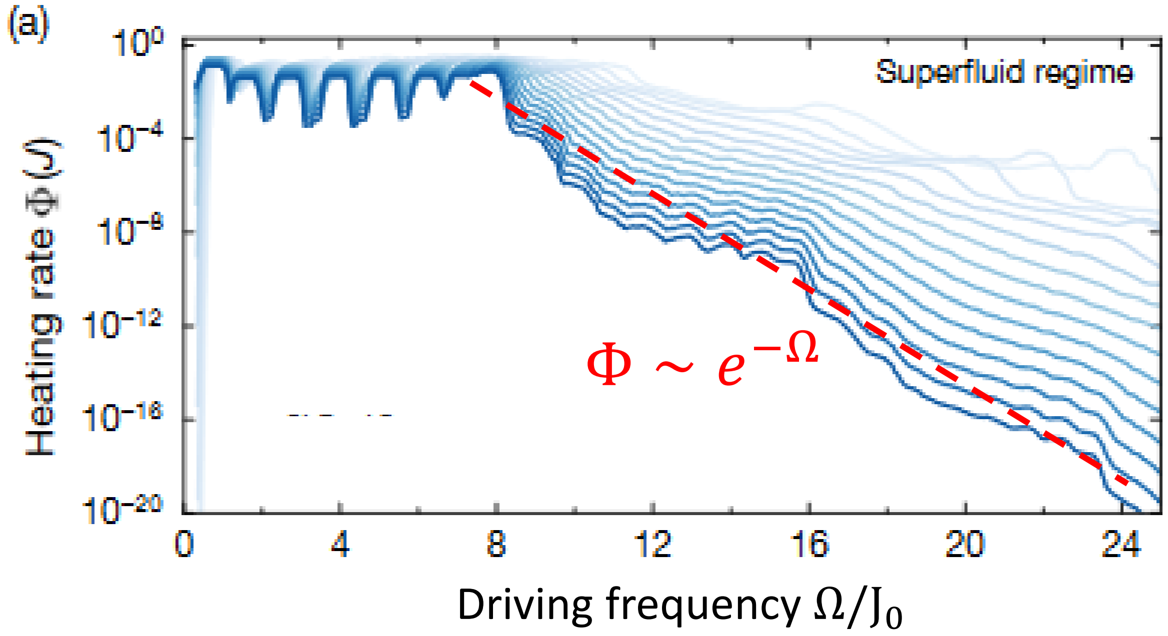
$$H(t) = \sum \frac{U}{2} n_i^2 - J(t)\,(b_i^+ b_{i+1} + H.c.)$$



$$J(t) = J_0 + \delta J \cos(\Omega t)$$

- Non-integrable model

Rajak, Dana, Dalla Torre, PRB Rapid (2019)



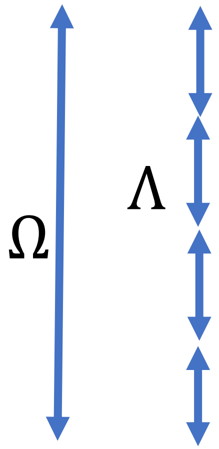
Rubio Abadal et al (Bloch group), PRX (2020)

Exponentially suppressed heating rate!

Emanuele Dalla Torre

Bar-Ilan University

Explanation 1: Rigorous bounds for quantum systems



Quantum system with a finite bandwidth

Perturbation theory: $\Phi \sim \epsilon^{\frac{\Omega}{\Lambda}} \sim \exp\left(-\frac{\Omega}{\Lambda}\right)$

Problem: Bose-Hubbard model has an infinite bandwidth: $\boldsymbol{H_{int} = \frac{U}{2}\sum_i n_i^2}$

Abanin, De Roeck, Ho, Huveneers (PRL 2015, CMP 2017)

Kuwahara, Mori, Saito, (Ann.of. Phys 2015, PRL 2015)

Explanation 2: Semiclassical rotor model

$$H(t) = \sum_i \frac{U}{2} n_i^2 \; - \bar{J}(t) \cos(\phi_i - \phi_{i+1})$$

ϕ_i = coordinate
n_i = angular momentum

- Chirikov many-body resonance: $n_i - n_{i+1} = \Omega$

Boltzmann probability: $\Phi \sim P = e^{-\frac{\frac{U}{2}n_i^2}{T}} \sim e^{-\frac{U\Omega^2}{2T}}$

See also lecture by Atanu Rajak V44.00010

Problem: wrong temperature dependence

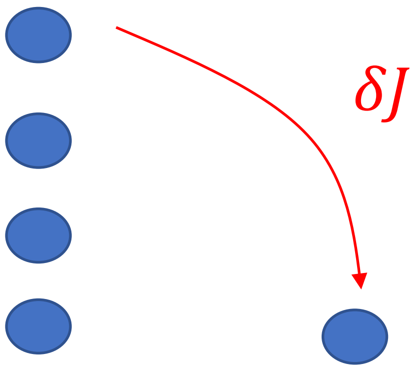
Emanuele Dalla Torre

Rajak, Dana, Dalla Torre, PRB Rapid (2019)

Bar-Ilan University

Explanation 3: Semiclassical approximation

$$H(t) = \sum_i \frac{U}{2} n_i^2 - J(t)\,(b_i^+ b_{i+1} + H.c.)$$



$$\Omega = U\Delta n$$

Particles' number conservation!

- Grand-canonical ensemble $\Phi \sim P = e^{-\frac{Un^2}{T} - \lambda n}$

Statistical-mechanics calculation

$$\Phi = \frac{(\delta J)^2 \hbar\Omega}{12 J k_B T} \exp\left(-\log(2)\frac{\hbar\Omega}{U}\right).$$

Dalla Torre, arXiv:2005.07207

Statistical prethermalization of the Bose-Hubbard model

1. Classical chaotic systems show Floquet prethermalization

- Boltzmann distribution:

$$\Phi \sim P = \exp\left(-\frac{H_{\text{av}} - \mu N}{T}\right)$$

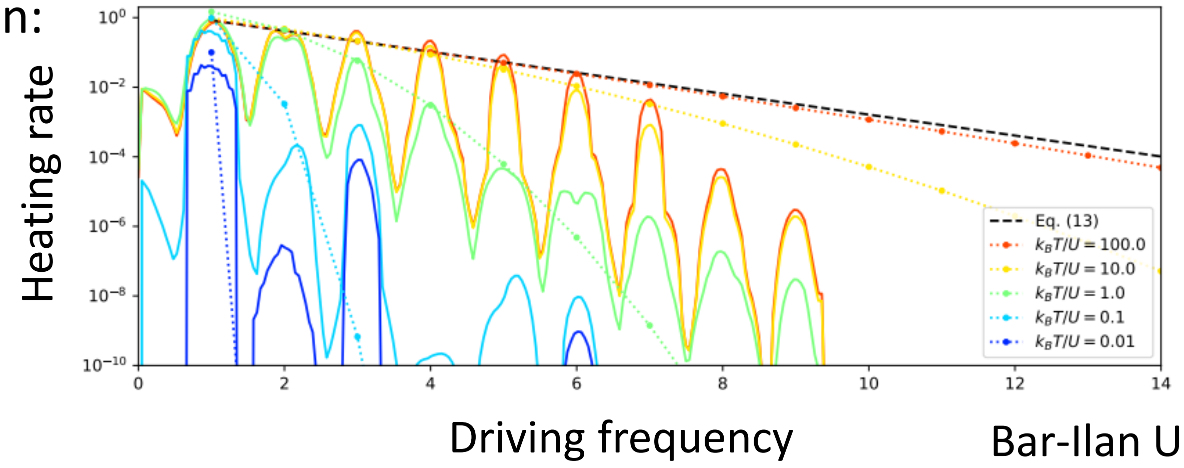
Rajak, Citro, Dalla Torre, JPA (2018)
Rajak, Dana, Dalla Torre, PRB (R) (2019)
Howell, Weinberg, Sels, Polkovnikov, Bukov, PRL (2020)
Saadia, Dalla Torre, Rajak, in preparation

See also lecture by Atanu Rajak V44.00010

2. Bose-Hubbard model: semiclassical approximation with particles conservation

- Agrees w/ exact diagonalization:
- High temperature expansion

$$\Phi = \frac{(\delta J)^2 \hbar\Omega}{12 J k_B T} \exp\left(-\log(2)\frac{\hbar\Omega}{U}\right).$$



arXiv:2005.07207

Emanuele Dalla Torre

Bar-Ilan University