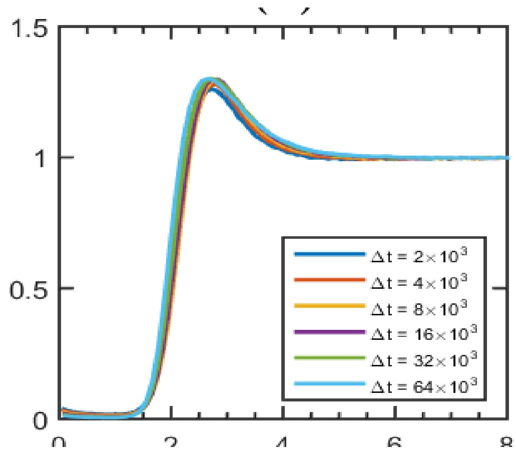
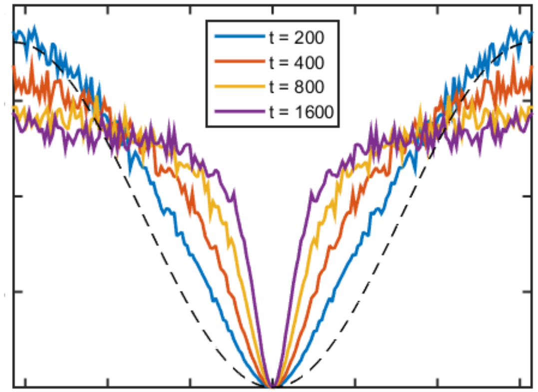
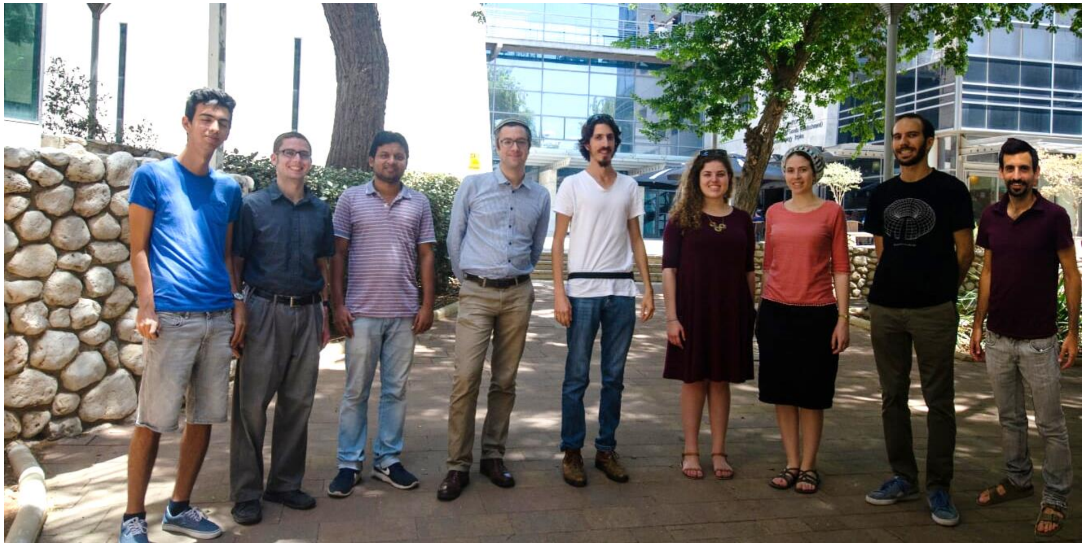
Emanuele Dalla Torre

Stability and pre-thermalization in chains of classical kicked rotors





Many-body quantum dynamics group



Atanu Rajak
(→ Kolkata)

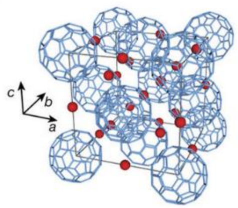
Itzhack Dana
Bar-Ilan University

Roberta Citro
University of Salerno

Why Floquet Engineering ?

Superconductors

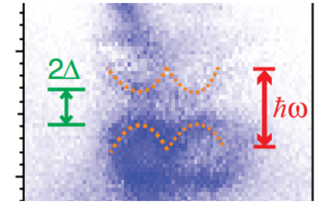
→ Light-enhanced superconductivity



[Cavalleri group – Nature 2016]

Topological insulators

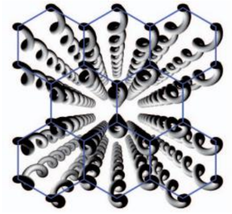
→ Floquet band structure



[Gedik group – Science 2013]

Wave guides

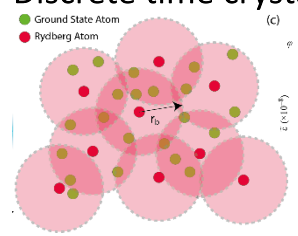
→ Photonic topological insulators



[Segev-Szameit group – Science 2018]

Rydberg atoms

→ Discrete time crystals



[Lukin group – Nature 2017]

Floquet Engineering - idea

Periodically driven Hamiltonian $H(t) = H(t+T)$

Stroboscopic time evolution $|\psi(nT)\rangle = \left(U(T)\right)^n |\psi_0\rangle$

Effective Floquet Hamiltonian $\boxed{U(T) = e^{-i\, H_F\, T}}$

$$|\psi(nT)\rangle = e^{-i\, H_F\, n\, T} |\psi_0\rangle$$

H_F is coooooI!

Eckardt, RMP 2017

Example – Paul trap

Video credit: Harvard Natural Sciences Lecture Demonstrations

The problem : heating

Break integrability = Add interactions

$\Downarrow$

Thermalize (Eigenstate thermalization hypothesis)

$\Downarrow$

Steady state = infinite temperature

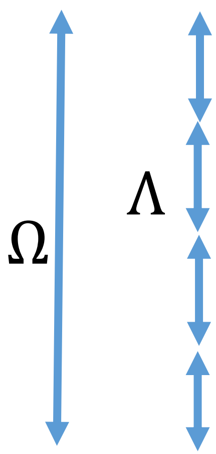
$$Z = e^{\beta H_F} \rightarrow e^{0\ H_F} = 1$$

How to prevent heating?

✓ Integrability

✓ Disorder (many-body localization)

✓ **High-frequency drive (prethermalization)**



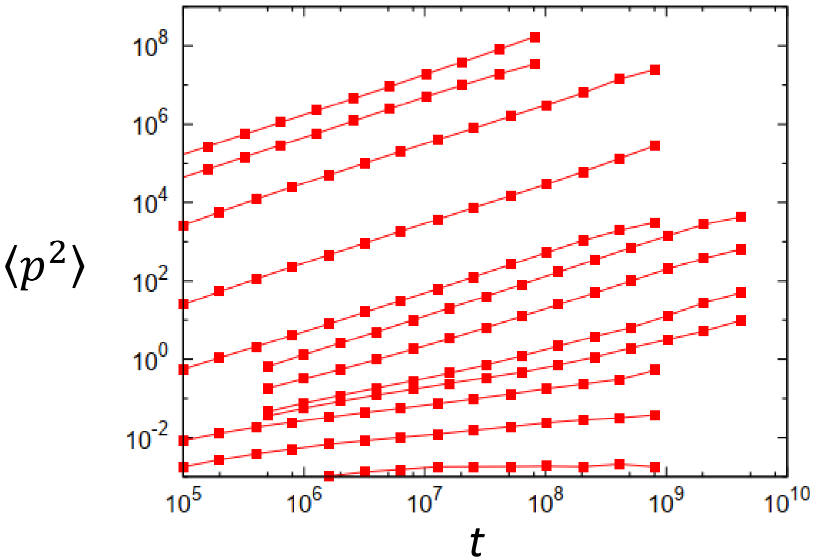
Quantum system with a finite bandwidth

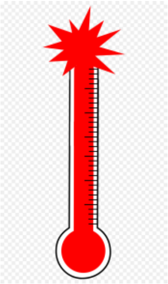
$$\frac{dH}{dt} \sim \epsilon^{\frac{\Omega}{\Lambda}} \sim \exp\left(-\frac{\Omega}{\Lambda}\right)$$

Abanin *etal* (PRL 2015) , (CMP 2017) - Kuwahara, Mori, Saito, (Ann.of. Phys 2015), (PRL 2015)

Classical systems with infinite bandwidth?

$$H = \sum_{j=1}^{N}\left[\frac{p_j^2}{2} - \kappa\cos(\phi_j - \phi_{j+1})\sum_{n=-\infty}^{+\infty}\delta(t - n\tau)\right].$$

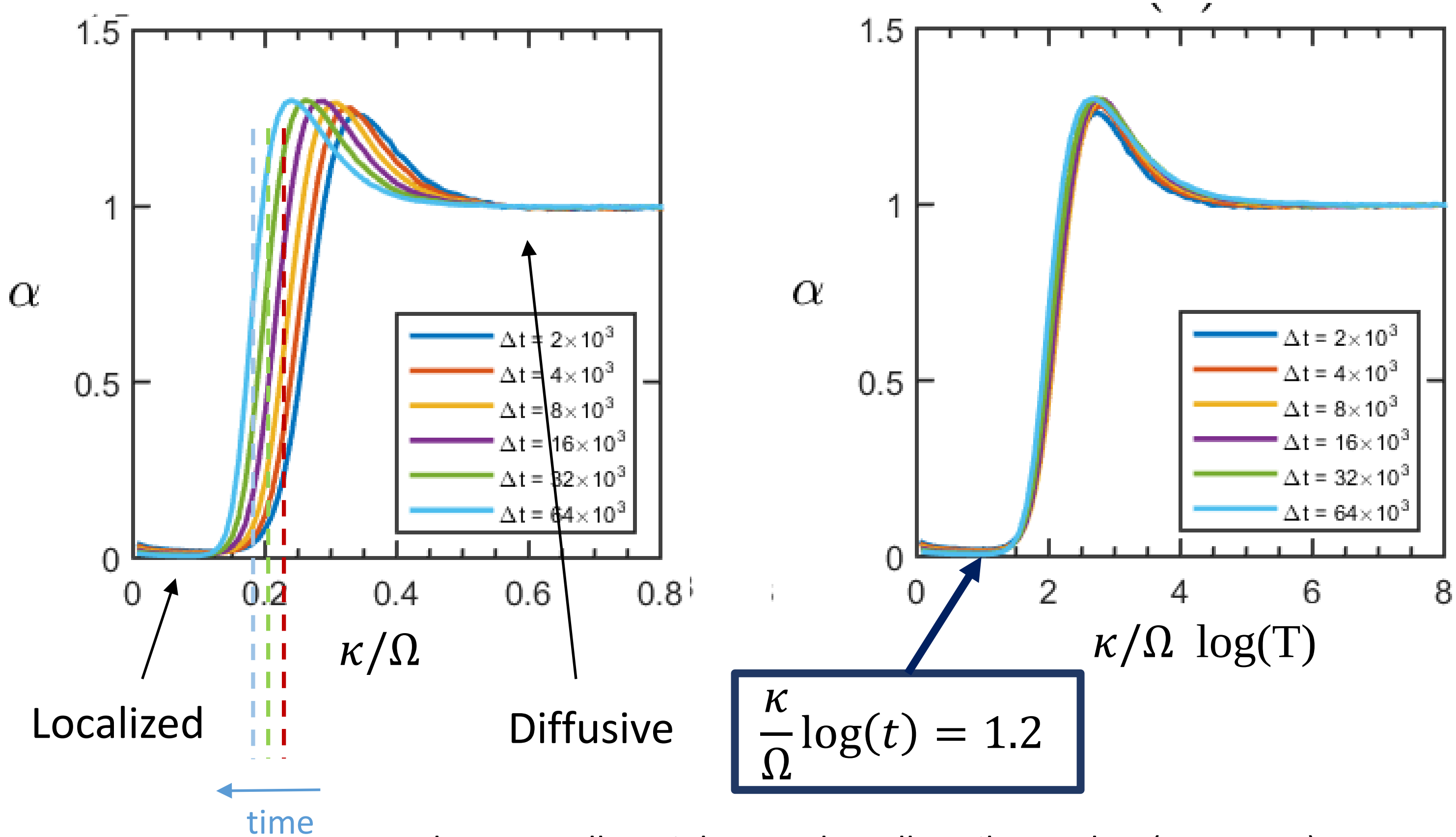




Kaneko & Konishi (1989) - Chirikov & Vecheslavov (1997)- Mulanski, Ahnert, Pikovski, Shepelyansky (2011)

Coupled kicked rotors – our results

$$\langle p(T)^2\rangle = A\, t^{\alpha}$$



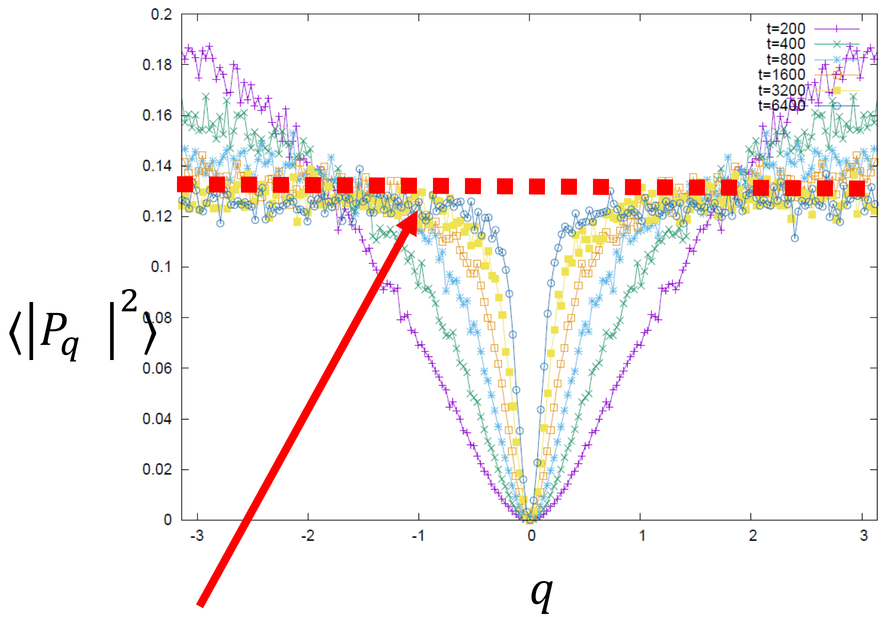
See also: Howell, Weinberg, Sels, Polkovnikov, Bukov (PRL, 2019)

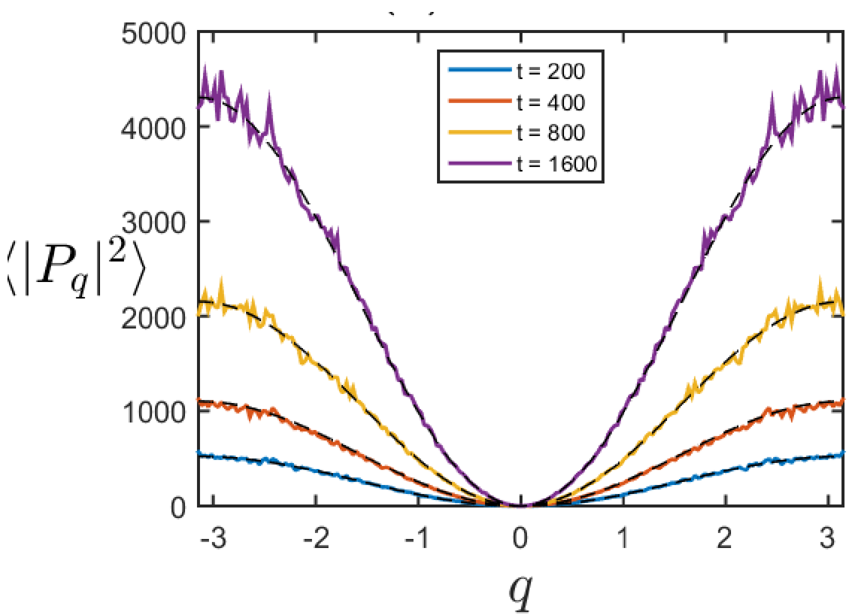
Coupled kicked rotors – momentum distrib.

$$P_q = \sum_n e^{iqn} p_n$$

Localized

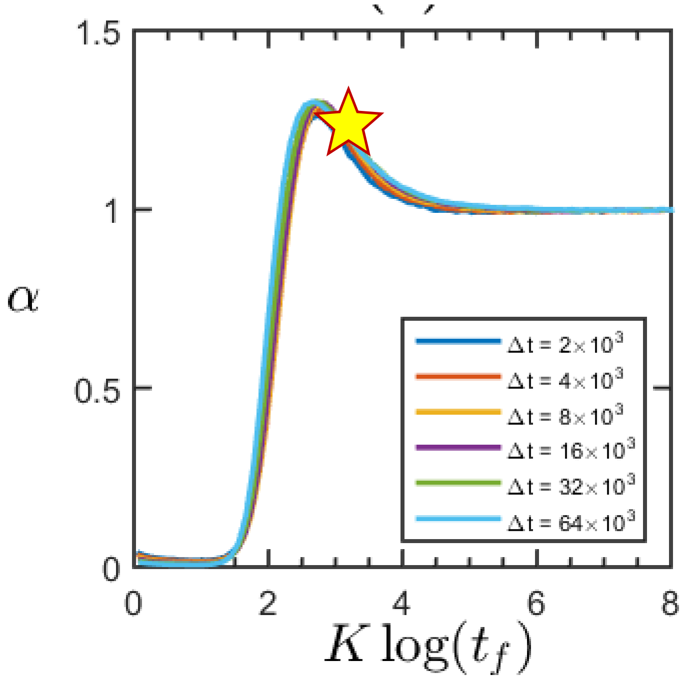
Diffusive

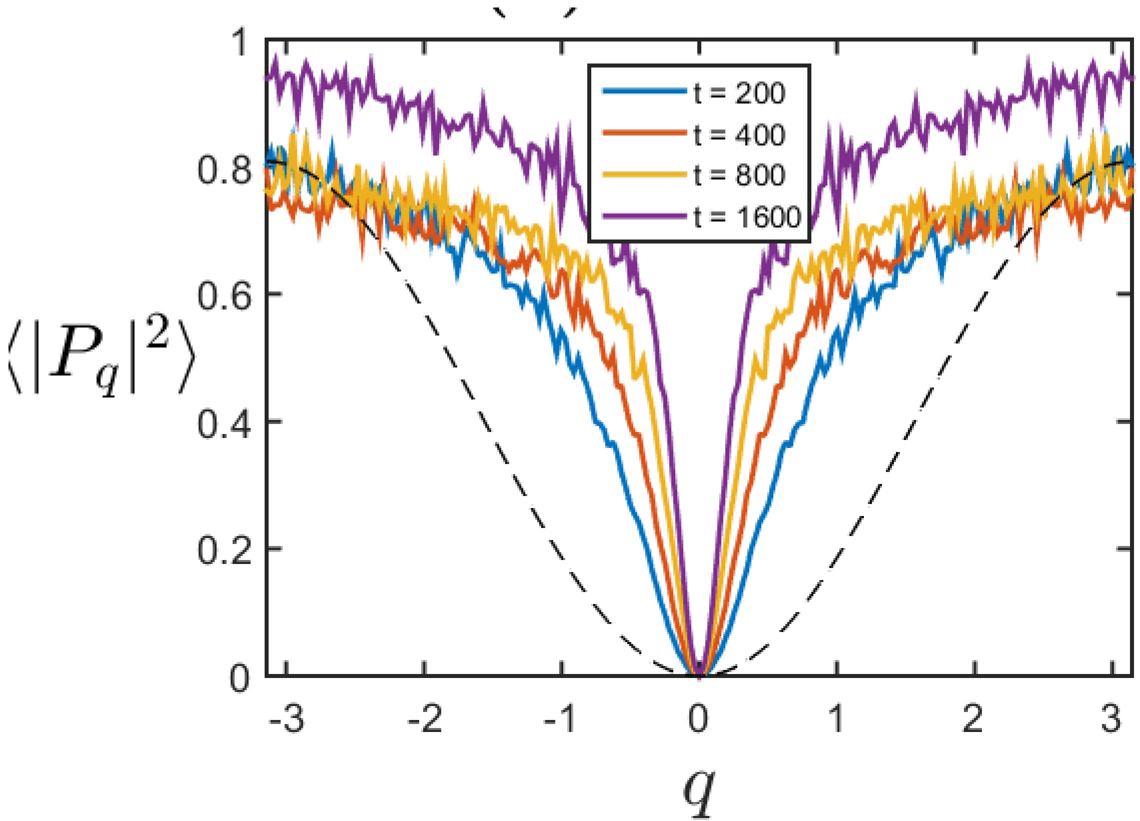




Prethermalization

Super-diffusion





Prethermalization in classical systems

$$H(t) = \sum_i \frac{p_i^2}{2} + K\Delta(t)\cos(\phi_i - \phi_{i+1}) \qquad \Delta(t) = \sum_n \delta(t - n\frac{2\pi}{\Omega})$$

Localizations threshold

$$\frac{\kappa}{\Omega}\log(t^*) = 1.2 \quad \Rightarrow \quad t^* = \exp\left(1.2\,\frac{\Omega}{\kappa}\right)$$

$$\boxed{\Omega \to \infty}$$

~~High-frequency suppression of heating (Floquet Hamiltonian)~~

$$\boxed{K \to 0}$$

~~Reduced diffusion close to integrability (Arnold diffusion)~~

Prethermalization in classical systems : 1,2,3

1. Boltzmann distribution : $Z = \exp\left(-\frac{H_F}{T}\right)$

$$H_F = \sum_i \frac{p_i^2}{2} + \kappa\Omega\cos(\phi_i - \phi_{i+1})$$

2. Temperature = energy of the initial state : $T = \kappa\Omega$

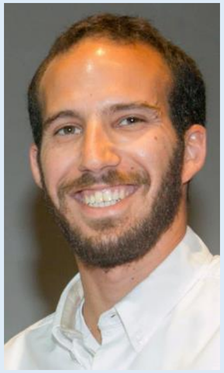
3. Heating = resonance : $p_i - p_{i+1} = \mathrm{m}\,\Omega$

$$\Rightarrow \quad t^* \sim \exp\left(-\frac{\Omega}{\kappa}\right)$$

Advertisements

Coupled parametric oscillators: theory and experiment

Dynamics/Theory of coupled parametric oscillators beyond coupled Ising spins
(arxiv: TODAY)



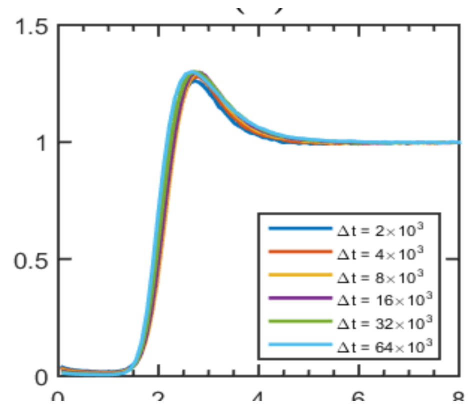
Dicke superradiance and lasing in open quantum systems

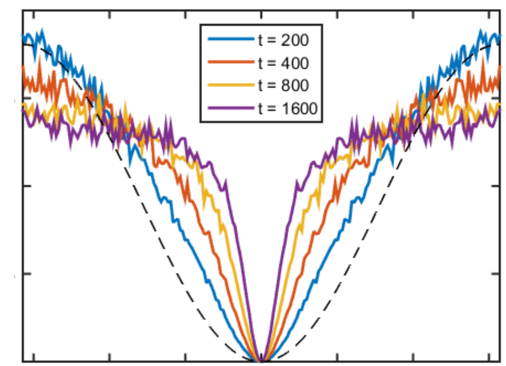
Introduction to the Dicke model: from equilibrium to nonequilibrium and viceversa
(Adv. Q. Tech., 2019)

Main result:

Exponentially long-lived prethermal state

in many-body classical kicked rotors





NEW! Mechanism: low energy initial state $t = e^{-\frac{\Omega}{T_{\mathrm{eff}}}}$

ISRAEL SCIENCE FOUNDATION

Citro, Dalla Torre, et al, Annals of Physics (2015)
Rajak, Citro, Dalla Torre (J. Phys. A: Math. Theor. 51 465001 (2018))
Rajak, Dana, Dalla Torre (in prep.)

Extra slides

Coupled kicked rotors – quadratic expansion

$$H = \frac{1}{2}\sum_q \left[|P_q|^2 + K(q)|\phi_q|^2 \sum_{n=-\infty}^{+\infty} \delta(t - n\tau)\right],$$

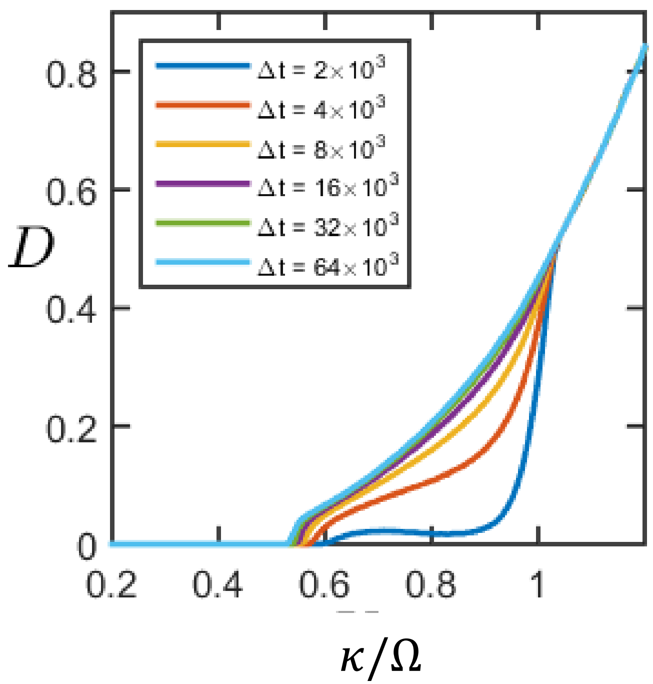
$$K(q) = \frac{4\kappa}{\Omega}\sin^2\left(\frac{q}{2}\right).$$

Kicked rotor
("Chirikov standard map")

→ Transition at $\kappa/\Omega = 1$

Coupled kicked rotors – quadratic instability

Initial state: $\phi_j \approx 0$



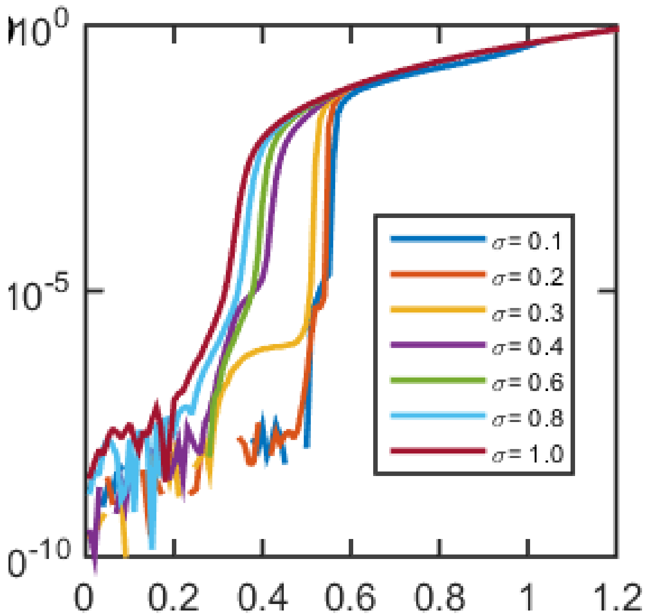
$$H^4 = -\frac{\kappa}{24}\sum_{j=1}^{N}(\phi_j - \phi_{j+1})^4 \sum_{m=1}^{\infty} \cos\left(\frac{2\pi m}{\tau}t\right),$$

$$2\pi m \leq 4\cos^{-1}(1 \ -2\kappa/\Omega)$$

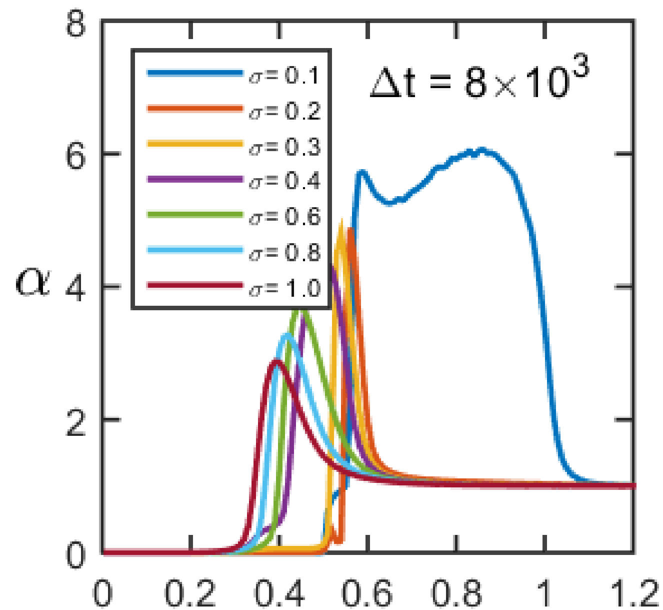
$$m = 4 \ \Rightarrow \ \frac{\kappa}{\Omega} > 0.5$$

Coupled kicked rotors – from quadratic to marginal

Initial state: $\langle \phi_j^2 \rangle = \sigma$



κ/Ω



κ/Ω

Finite size effect