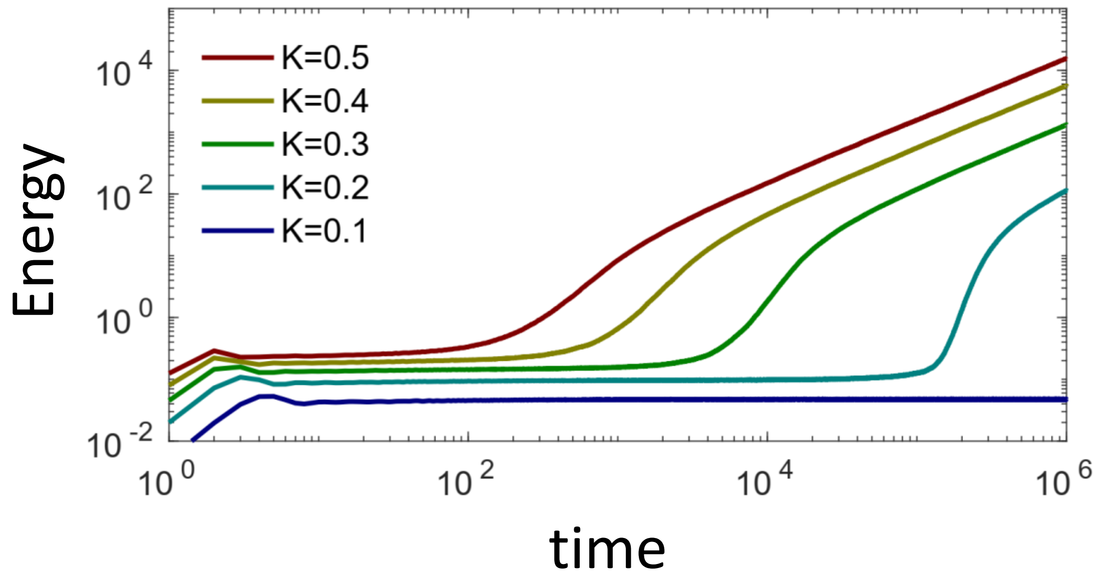
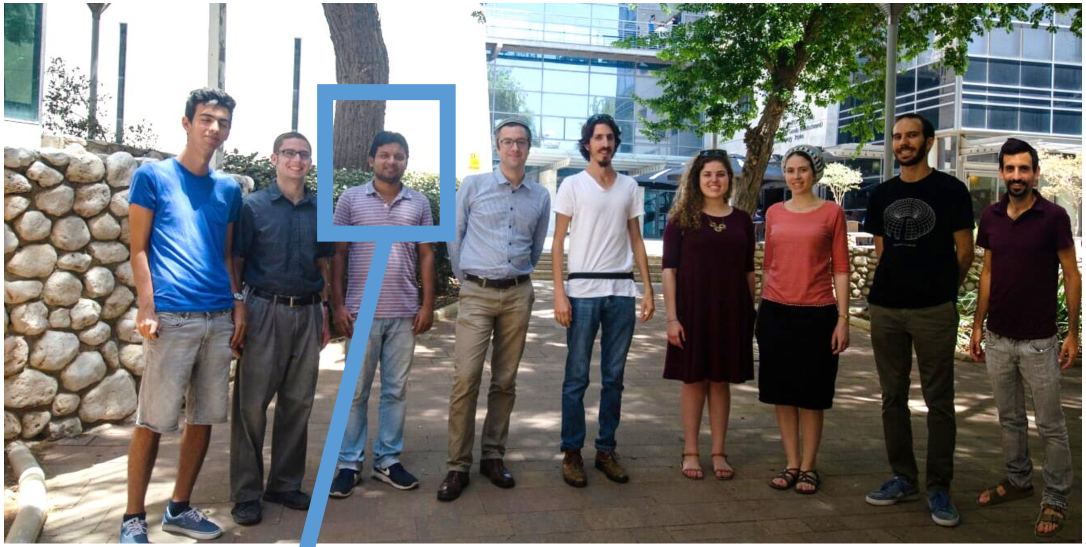
Emanuele Dalla Torre

Quantum-Inspired prethermalization in **classical** many-body kicked rotors



Many-body (quantum) dynamics group



Angelo Russomanno
(→ ICTP Trieste)

Atanu Rajak
(→ Kolkata)

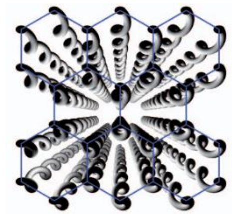
Roberta Citro
University of Salerno

Itzhack Dana
Bar-Ilan University

Why periodically-driven systems?

Metamaterials

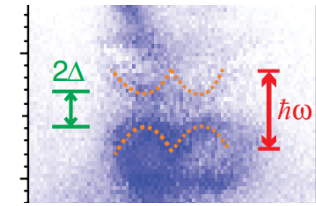
→ Photonic topological insulators



[Segev-Szameit – Nature 2013]

Topological insulators

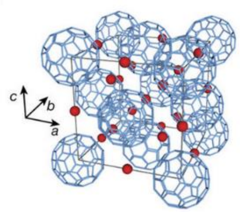
→ Floquet band structure



[Gedik – Science 2013]

Superconductors

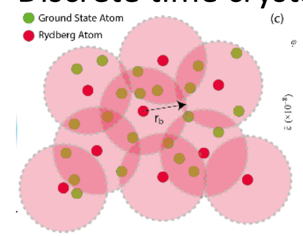
→ Light-enhanced superconductivity



[Cavalleri – Nature 2016]

Rydberg atoms

→ Discrete time crystals



[Lukin – Nature 2017]

See also: talks by Monika Aidelsburger (Tuesday) & Qian Niu (today)

Floquet Engineering - idea

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

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

$\updownarrow$

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 coooool!

Eckardt, RMP 2017

Example – Paul trap

Video credit: Harvard Natural Sciences Lecture Demonstrations

The problem : heating

Interactions = Diffusion

Thermalize to infinite temperature

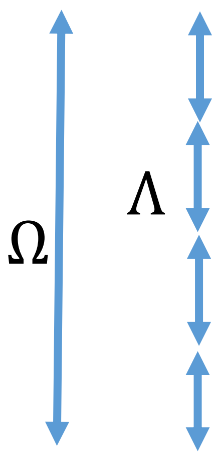
Long time: $Z = e^{\beta H_F} \rightarrow e^{0\ H_F} = 1$

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, De Roeck, Ho, Huveneers (PRL 2015, CMP 2017) - Kuwahara, Mori, Saito, (Ann.of. Phys 2015, PRL 2015)

Systems with infinite bandwidth?

Kicked rotor $$H = \frac{p^2}{2} - \kappa \cos(\phi) \sum_{n=-\infty}^{n=\infty} \delta(t - n\tau)$$

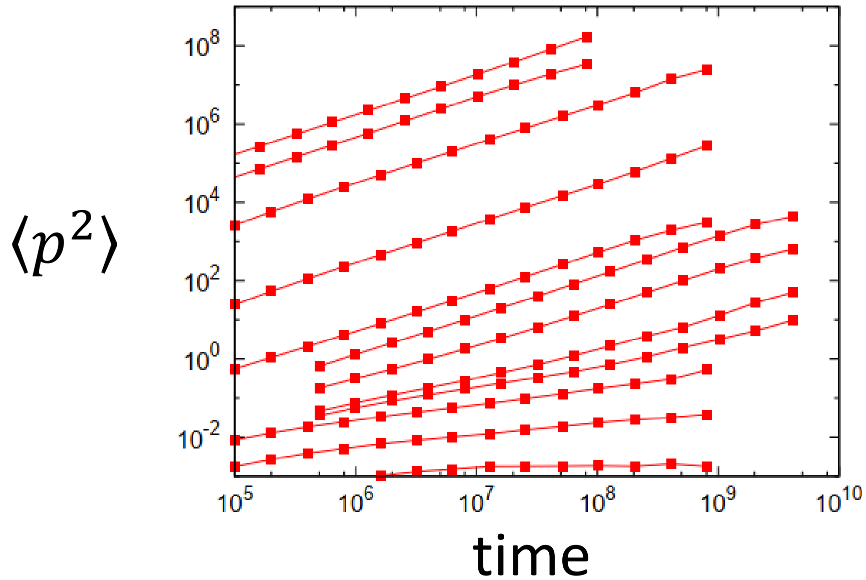
No heating: dynamical localization (quantum)

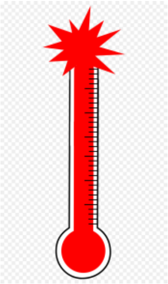
Shmuel Fishman z"l (1948-2019)

Fishman, Grempel, Prange (1982)

Coupled kicked rotors

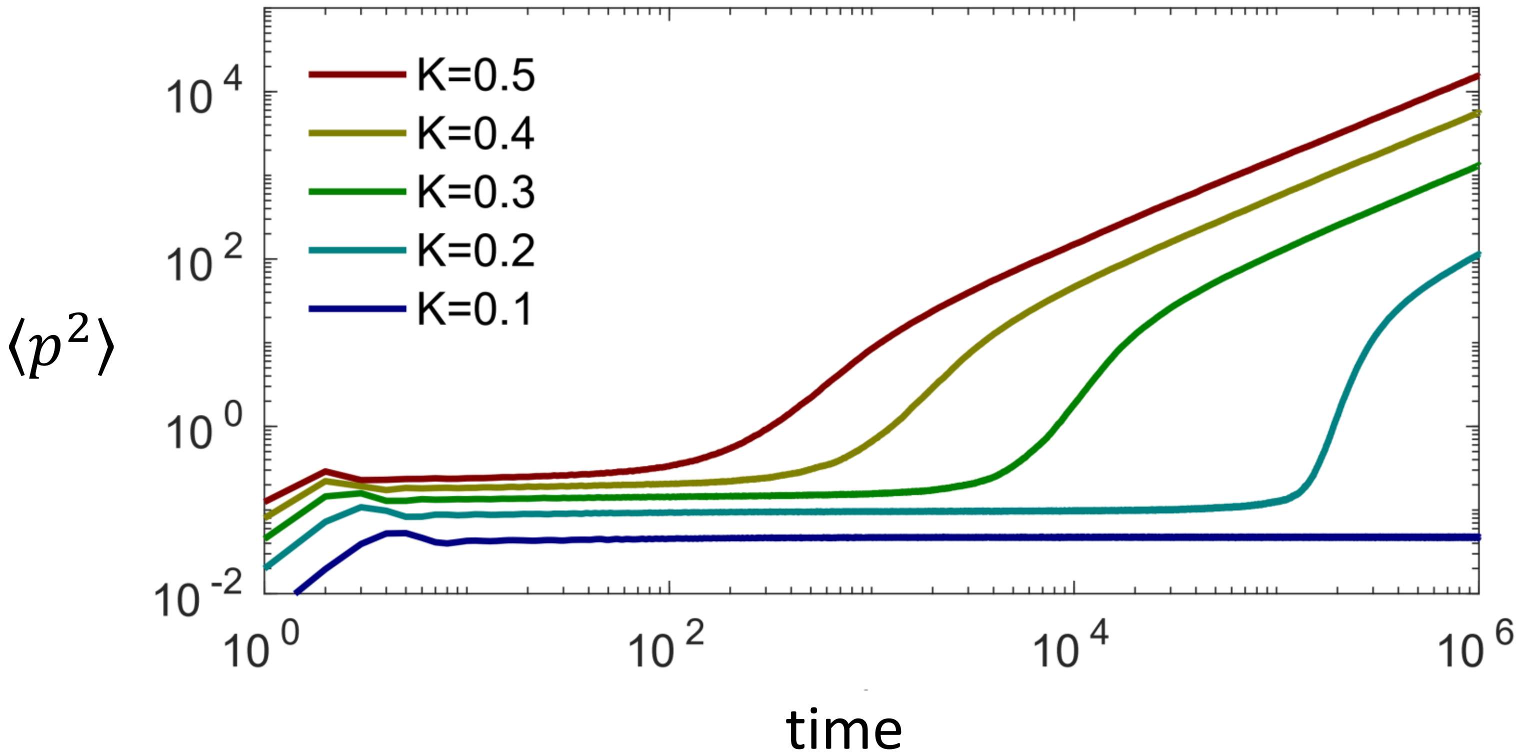
$$H = \sum_{j=1}^{N} \left[\frac{p_j^2}{2} - \kappa \cos(\phi_j - \phi_{j+1}) \sum_{n=-\infty}^{+\infty} \delta(t - n\tau) \right].$$





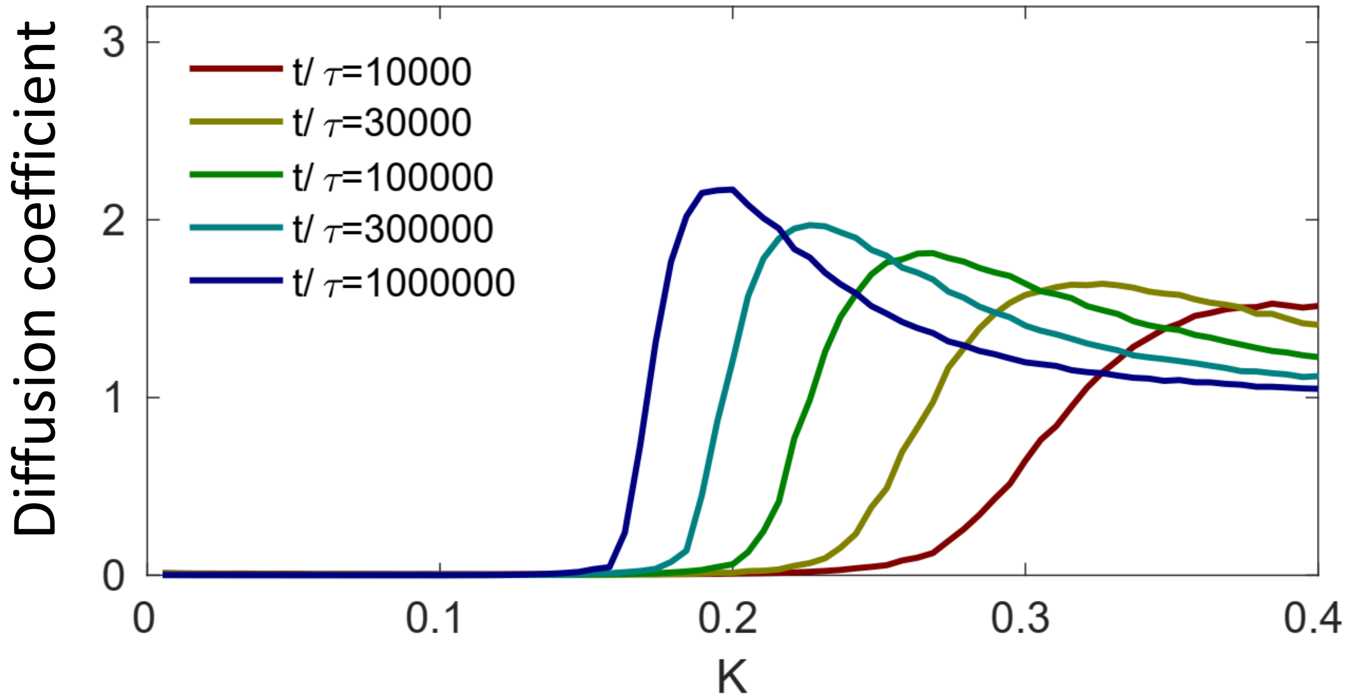
Kaneko & Konishi (1989) - Chirikov & Vecheslavov (1997)- Mulanski, Ahnert, Pikovski, Shepelyansky (2011)

Coupled kicked rotors – our results



A. Rajak, R. Citro, E. G. Dalla Torre, JPA (2018)   A. Rajak, I. Dana, E. G. Dalla Torre (unpublished)

Coupled kicked rotor – our results



Prethermalization in classical systems

$$H(t) = \sum_i \frac{p_i^2}{2} + K\Delta(t)\cos(\phi_i - \phi_{i+1})$$

$$\Delta(t) = \sum_n \delta(t - n\frac{2\pi}{\Omega})$$

Localizations threshold

$$\frac{\kappa}{\Omega}\log\left(\frac{t}{\tau}\right) = 2 \quad \Rightarrow \quad \frac{t^*}{\tau} = \exp\left(\frac{2\Omega}{\kappa}\right)$$

$$\boxed{\Omega \rightarrow \infty}$$

$$\boxed{K \rightarrow 0}$$

High-frequency suppression of heating (Floquet Hamiltonian)

Reduced diffusion close to integrability (Arnold diffusion)

A new mechanism for prethermalization

1. Prethermal state $Z = \exp\left(-\frac{H_F}{T^*}\right)$

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

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

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

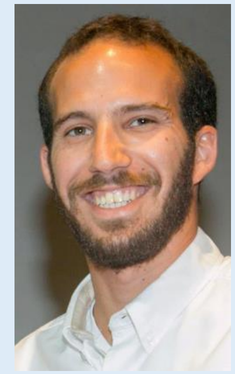
$$t^* \sim \exp\left(\frac{\mathrm{p}^2}{2\mathrm{T}^*}\right) \sim \exp\left(\frac{2\Omega}{\kappa}\right)$$

Advertisements

Marcello Calvanese Strinati

Coupled parametric oscillators: theory and experiment

Dynamics/Theory of coupled parametric oscillators beyond coupled Ising spins
(arxiv: 1901.07372)



Mor Roses

Dicke superradiance and lasing in open quantum systems

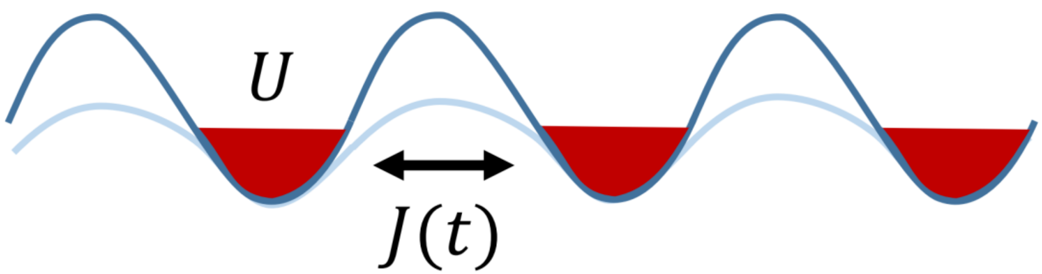
Introduction to the Dicke model: from equilibrium to nonequilibrium and viceversa
(Adv. Q. Tech., 2019)

Main result:

Exponentially long-lived prethermal state

in many-body classical kicked rotors

NEW mechanism: low-energy initial state $t = e^{-\frac{p^2}{T^*}}$



ISRAEL SCIENCE FOUNDATION

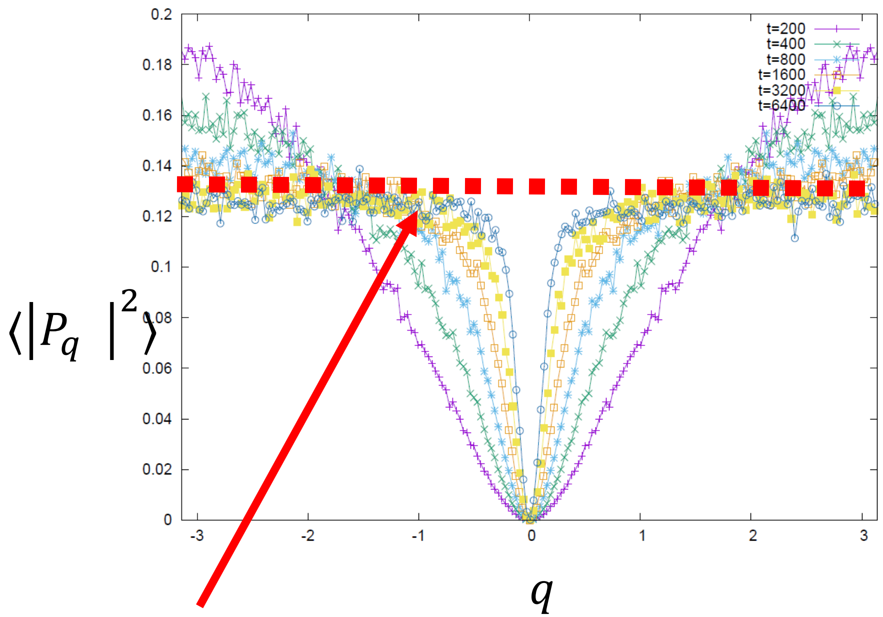
Citro, Dalla Torre, et al, Annals of Physics (2015)
Rajak, Citro, Dalla Torre (J. Phys. A: Math. Theor. 51 465001 (2018))
Rajak, Dana, Dalla Torre (in prep.)

Extra slides

Coupled kicked rotors – momentum distrib.

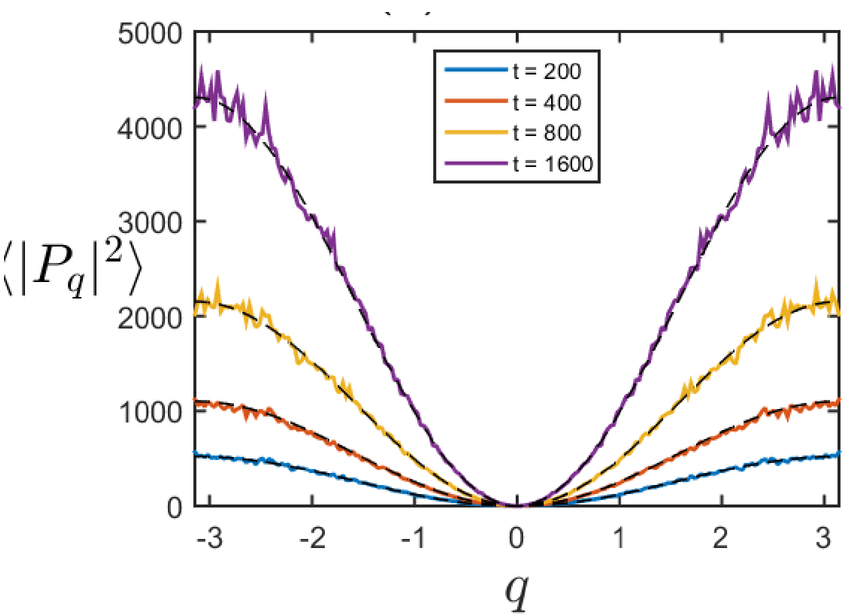
$$P_q = \sum_n e^{iqn} p_n$$

Localized

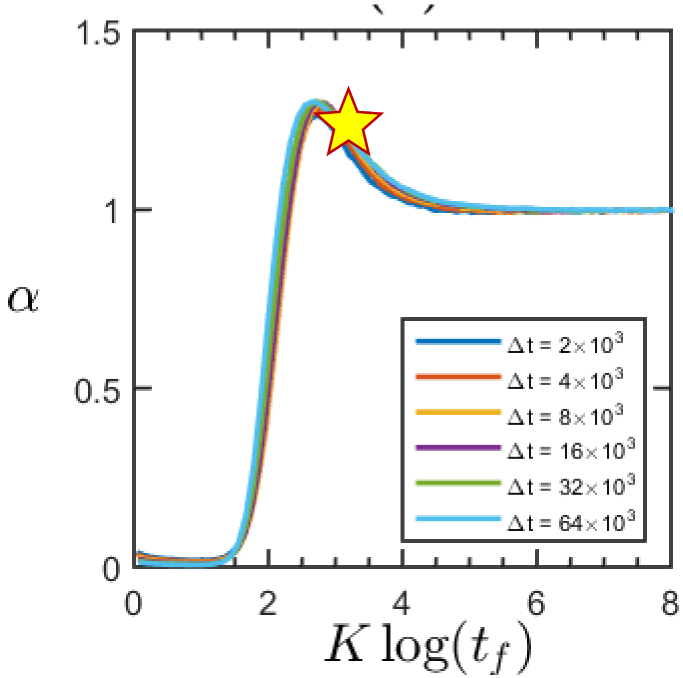


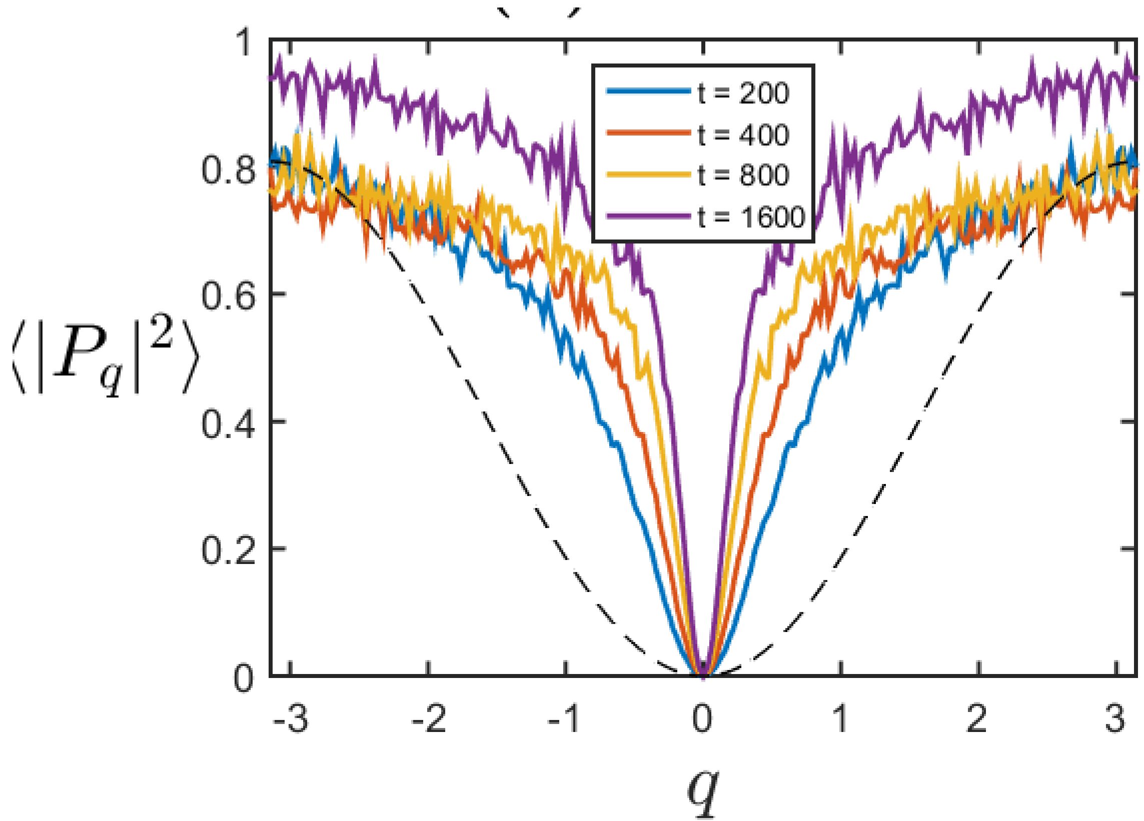
Prethermalization

Diffusive



Super-diffusion





Coupled kicked rotors – quadratic expansion

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

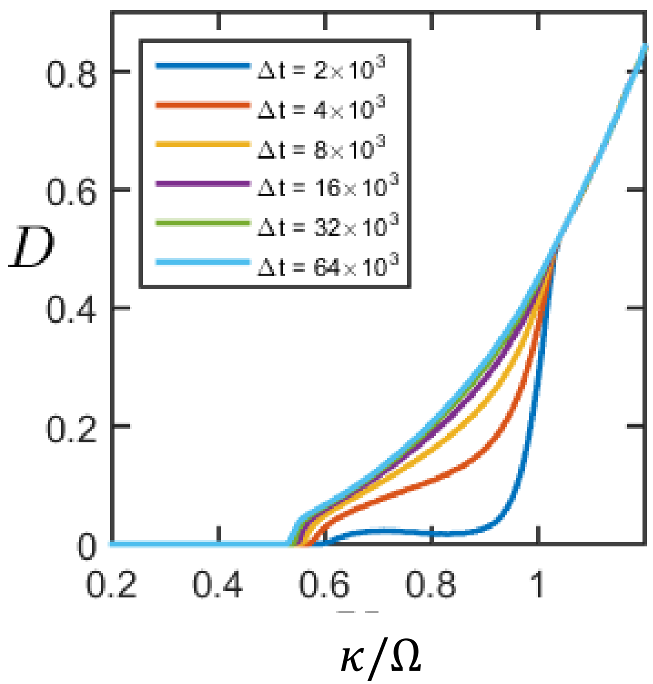
$$K(q) = \frac{4\kappa}{\Omega}\sin^2(\frac{q}{2}).$$

Kicked rotor
("Chirikov standard map")

→ Transition at $\kappa/\Omega = 1$

Coupled kicked rotors – quadratic instability

Initial state: $\phi_j \approx 0$



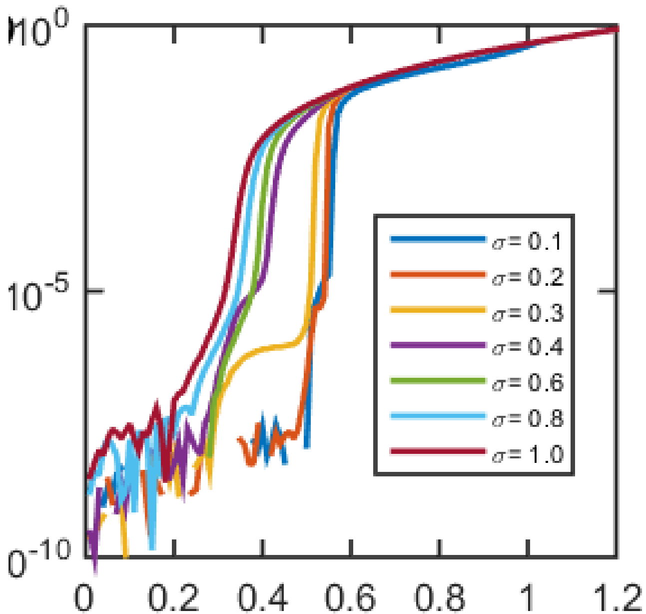
$$H^4 = -\frac{\kappa}{24}\sum_{j=1}^{N}(\phi_j - \phi_{j+1})^4 \sum_{m=1}^{\infty} \cos\left(\frac{2\pi m}{\tau}t\right),$$

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

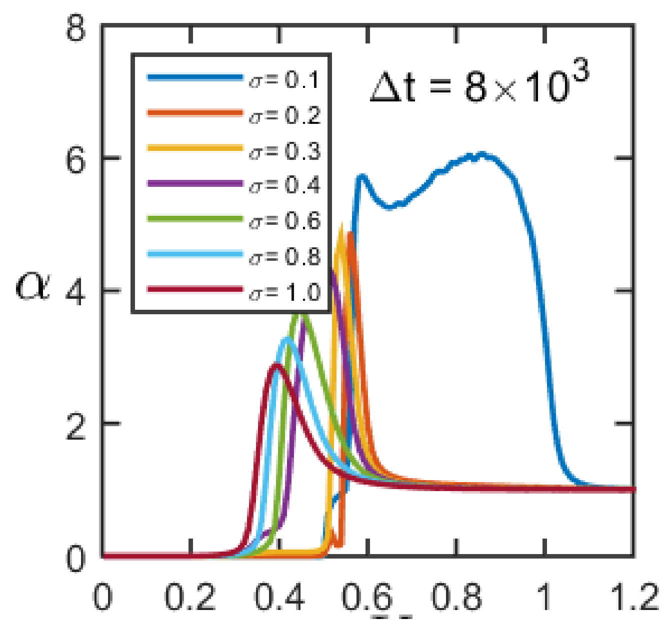
$$m = 4 \quad \Rightarrow \quad \frac{\kappa}{\Omega} > 0.5$$

Coupled kicked rotors – from quadratic to marginal

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



κ/Ω



κ/Ω

Finite size effect