dynamical resistivity of a few interacting fermions to the time-dependent potential barrier

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abstract

We study the dynamical response of a harmonically trapped two-component few-fermion mixture to the external Gaussian potential barrier moving across the system. The simultaneous role played by inter-particle interactions, rapidity of the barrier, and the fermionic statistics is explored for systems containing up to four particles. We show that the dynamical properties of the system crucially depend on non-trivial mutual relations between temporal many-body eigenstates, and in consequence, they lead to volatility of the dynamics. Counterintuitively, imbalanced systems manifest much higher resistivity and stability than their balanced counterparts.

the model

- two distinguishable flavors of fermions (↑ and ↓)
- both flavors have equal masses
- opposite spins do interact via sort range δ-like potential

$$\hat{\mathcal{H}}(x_0) = \sum_\sigma \int \mathrm{d}x\, \hat\Psi^\dagger_\sigma(x)\left[H_0 + U(x_0)\right]\hat\Psi_\sigma(x) + g\int \mathrm{d}x\, \hat\Psi^\dagger_\uparrow(x)\hat\Psi^\dagger_\downarrow(x)\hat\Psi_\downarrow(x)\hat\Psi_\uparrow(x)$$

$$H_0 = -\frac{\hbar^2}{2m}\frac{\mathrm{d}^2}{\mathrm{d}x^2} + \frac{m\Omega^2}{2}x^2 \qquad U(x_0) = \frac{U_0}{\sqrt{\pi}\beta}\mathrm{e}^{-(x-x_0)^2/\beta^2}$$

$$x_0(t) = A\cos(\omega t)$$

(anti-)commutation relations

- the same spins

$$\left\{\hat\Psi_\sigma(x), \hat\Psi^\dagger_\sigma(x')\right\} = \delta(x-x')$$
$$\left\{\hat\Psi_\sigma(x), \hat\Psi_\sigma(x')\right\} = 0$$

- opposite spins

$$\left[\hat\Psi_\uparrow(x), \hat\Psi^\dagger_\downarrow(x')\right] = 0$$
$$\left[\hat\Psi_\uparrow(x), \hat\Psi_\downarrow(x')\right] = 0$$

the method

- representation in the time-independent single-particle basis

$$\hat\Psi_\downarrow(x) = \sum_i \phi_i(x)\hat{a}_i, \qquad \hat\Psi_\uparrow(x) = \sum_i \phi_i(x)\hat{b}_i$$

$$\hat{\mathcal{H}}(x_0) = \sum_i\left(i+\frac{1}{2}\right)\left(\hat a^\dagger_i\hat a_i + \hat b^\dagger_i\hat b_i\right) + \sum_{ij} U_{ij}(x_0)\left[\hat a^\dagger_i\hat a_j + \hat b^\dagger_i\hat b_j + \mathrm{h.c.}\right] + g\sum_{ijkl} I_{ijkl}\hat b^\dagger_i\hat a^\dagger_j\hat a_k\hat b_l.$$

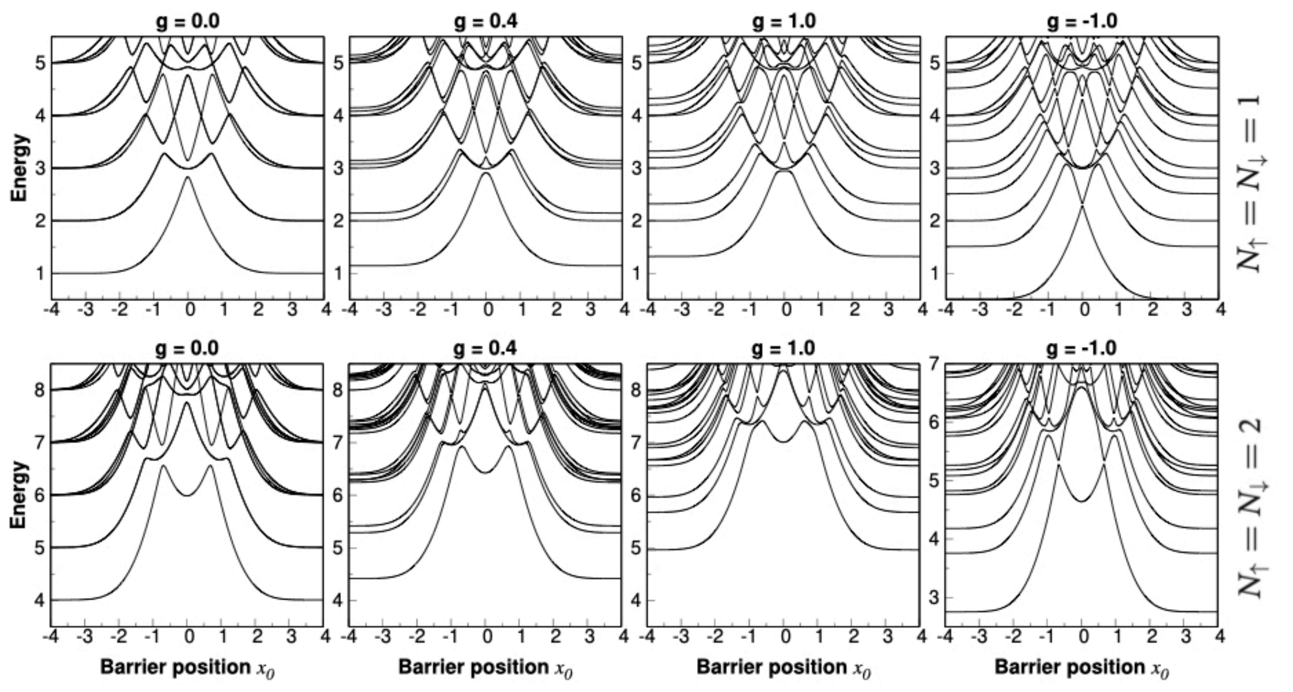
- exact many-body dynamics of the system

$$i\frac{\mathrm{d}}{\mathrm{d}t}|\psi(t)\rangle = \hat{\mathcal{H}}(x_0(t))|\psi(t)\rangle \qquad |\psi(t=0)\rangle = |\mathrm{G}_0\rangle$$

- temporal fidelity as a measure of the system's response

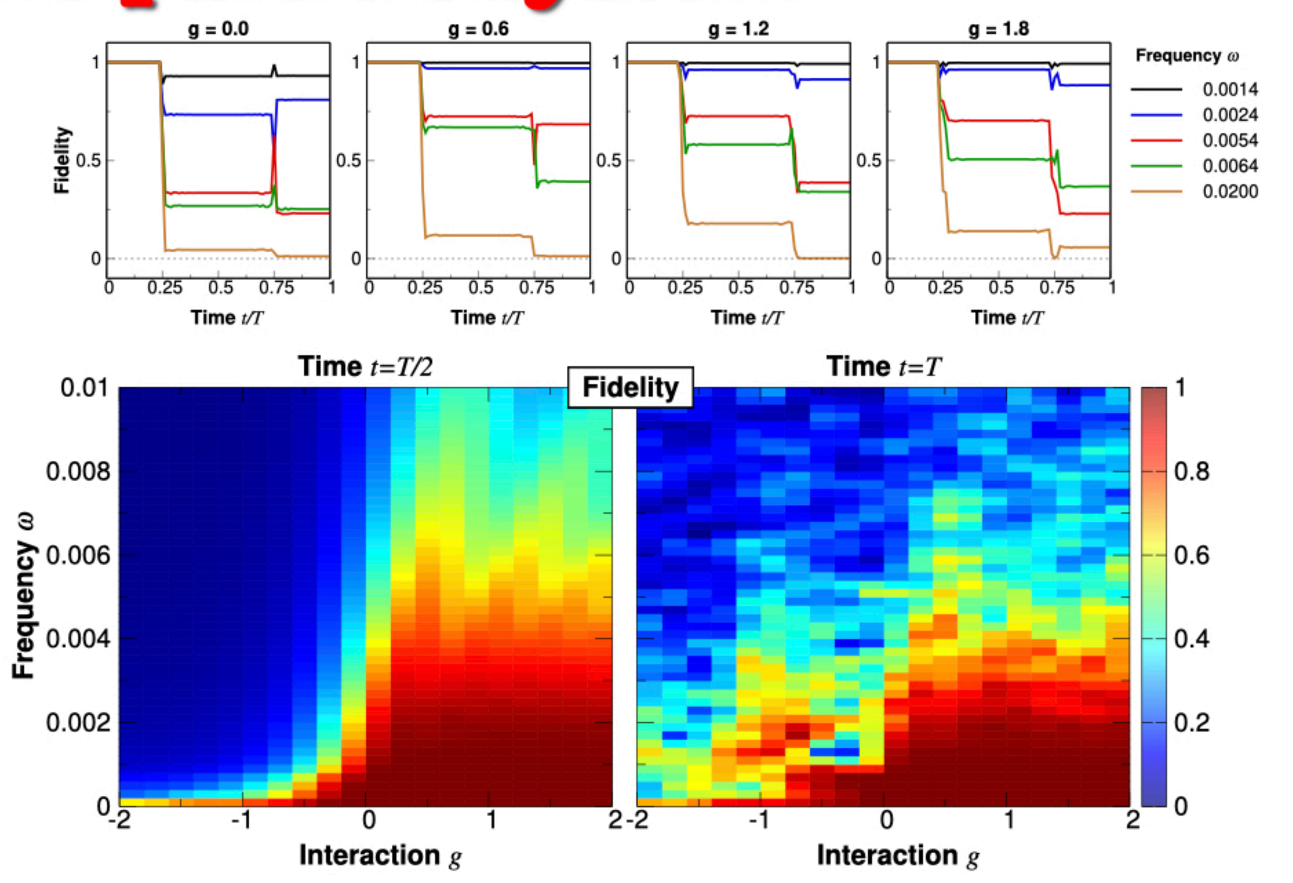
$$\mathcal{F}_\omega(t) = |\langle\psi(t)|\mathrm{G}(x_0(t))\rangle|^2$$

the many-body spectrum



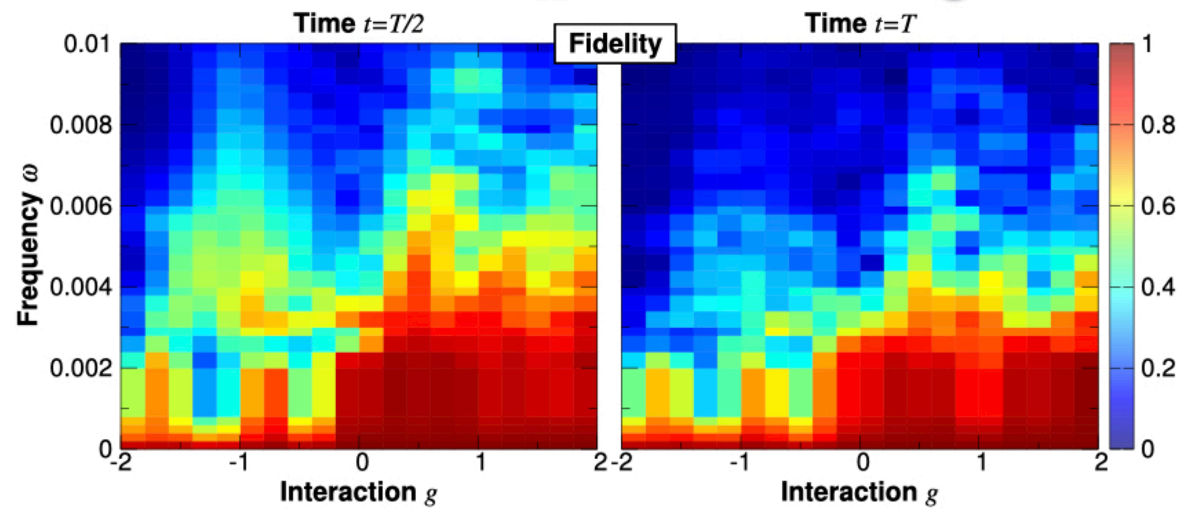
note a substantial difference when the barrier passes the center of the trap

two-particle system



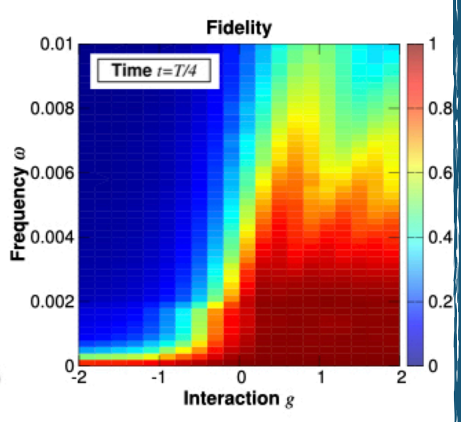
attractively interacting system is less resistant

balanced four-particle system

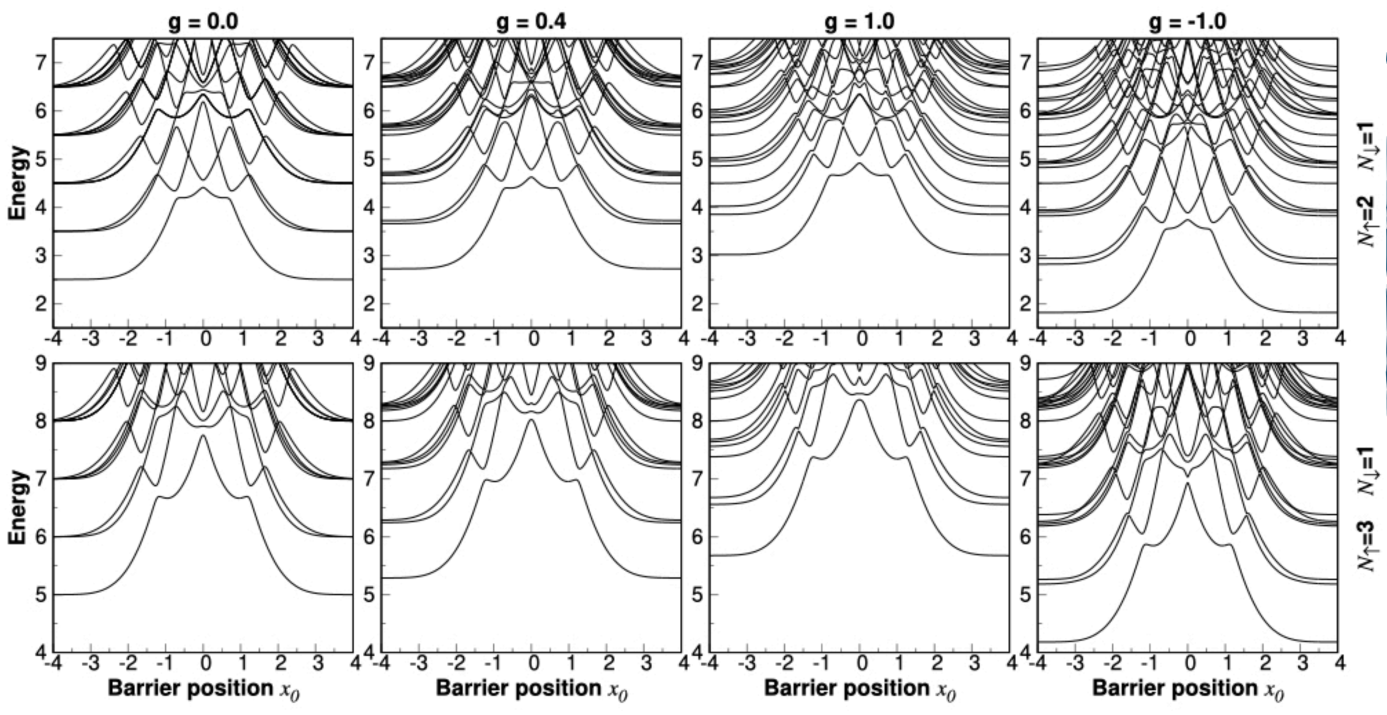


the temporal fidelity is unpredictable not only at the final moment $t = T$ but also after the first transition $t = T/2$

when the barrier is in the middle ($t = T/4$) the quasi-degeneracy of the spectrum is reached only once and therefore the dynamical response of the system is much more regular

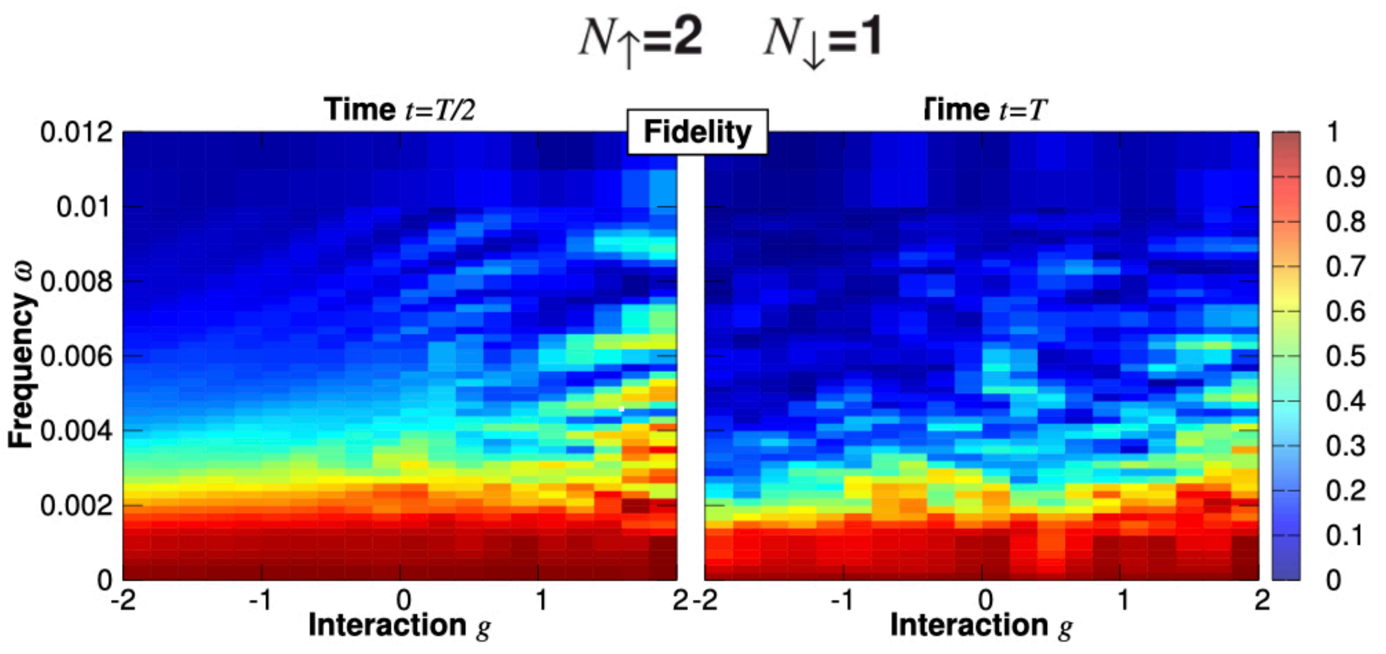


imbalanced systems - spectrum



note that the ground-state is always well-isolated

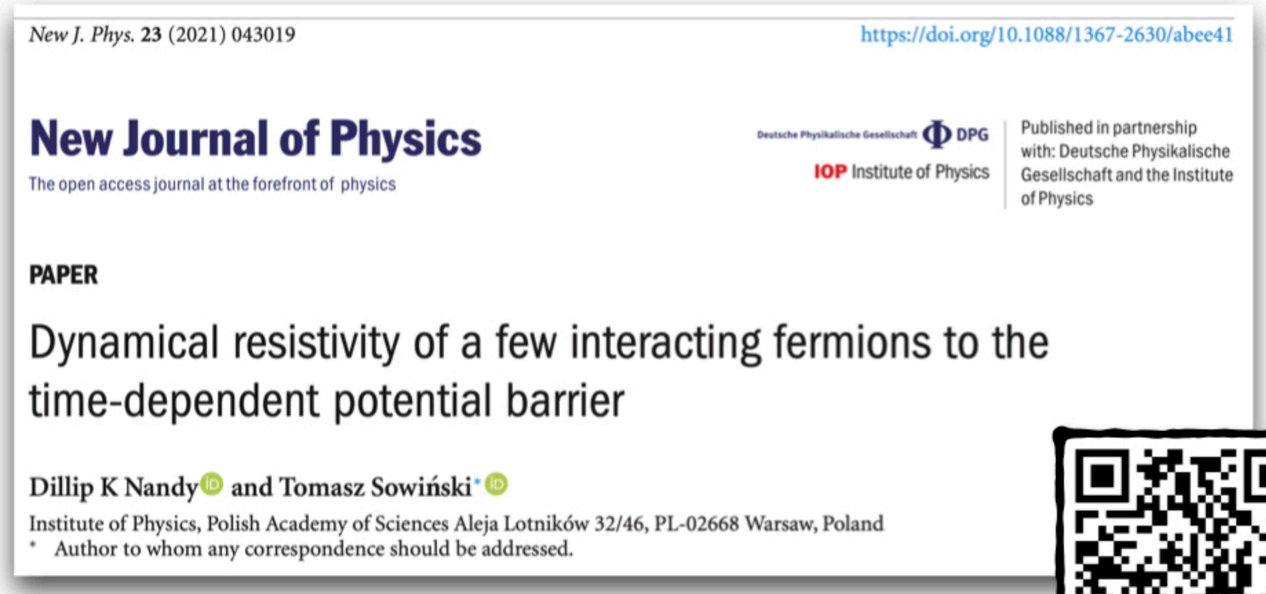
imbalanced systems - response



in contrast to balanced systems, the many-body ground state of imbalanced system is well-isolated also for attractive forces

this leads to higher resistivity and stability of the dynamics

references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