is destabilized by a small subsystem driven at much higher values of ϵ, or whether a modest amount of particles driven at small ϵ can stabilize an otherwise unstable system.

To investigate the impact of the spatial dependence of the drive, we consider a disorder-free spin-1/2 chain with nearest-neighbor Ising interactions and periodic driving through numerical simulations. When initialized in a fully magnetized state, such a system's magnetization is known to exhibit period-doubled oscillations for a time growing exponentially with system size, which we will call lifetime [14,43–45]. Interestingly, by reducing the rotation angle deviation ϵ for a single spin of the chain, we find a drastic enhancement of the magnetization lifetime of the entire chain, as if the single spin was acting like a metronome that keeps the other spins on beat. We employ a time-averaged effective description, which allows us to explain the observed behavior with the help of symmetry arguments for the bulk of the chain.

Building on these results, we study how generic initial states behave in the presence of a metronome spin. Again, we find analogous lifetime enhancements in magnetization autocorrelators, however, only for the outermost spins stemming from the existence of a topological edge mode. Finally, we present a system geometry in which these two mechanisms can be clearly discerned. Our results offer new insights into how local perturbations in the chain can have a strong impact on the overall lifetime of large systems. This opens up new possibilities in the design and implementation of extended, (meta)stable phases of matter out of equilibrium, even in systems without disorder.

Following this introduction, we first give a more detailed description of the investigated system and the numerical methods used in Sec. II. The results for bulk and edge stabilization are presented in Sec. III and subsequently discussed in Sec. IV.

II. MODEL AND METHODS

We study the effects of spatially nonuniform Floquet driving through numerical simulation of a spin-1/2 chain. The Floquet sequence investigated in this work consists of two parts: in a first step, the spins interact through nearest-neighbor Ising couplings with open boundary conditions, as shown in Fig. 1(a). Second, the spins are subjected to unitary rotations by $\pi(1-\epsilon_i)$, with i indicating the site index. We consider the case where the first spin is driven with $\epsilon_{i=1}=\epsilon'$ and all other spins with $\epsilon_{i>1}=\epsilon$ [Fig. 1(b)]. Thus, this configuration represents a uniformly driven chain with a local perturbation at one boundary site, obeying a spin-flip symmetry in the absence of z fields. One cycle of this time-periodic evolution is captured by the Hamiltonian

$$H=\begin{cases} H_{\rm int}=\sum_{i=1}^{L-1}J_{i,i+1}s_z^is_z^{i+1}+\sum_{i=1}^{L}h_is_z^i, & 0\leqslant t\leqslant t_1 \\ H_x=\sum_{i=1}^{L}(1-\epsilon_i)s_x^i, & t_1<t<t_1+\pi=:T \end{cases}, \tag{1}$$

with $s^i_{\{x,y,z\}}=\sigma^i_{\{x,y,z\}}/2$ being the single-spin operators. The evolution governed by this Hamiltonian induces (imperfect)

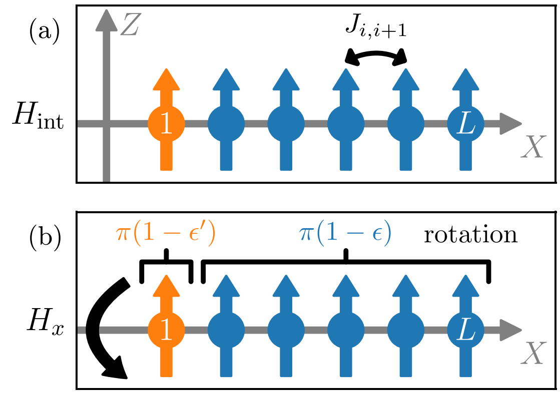

FIG. 1. An illustration of the two-step Floquet cycle of the one-dimensional (1D) system considered in this work. (a) The interaction phase of the cycle given by an Ising Hamiltonian with nearest-neighbor couplings. (b) The driving phase of the Floquet cycle, realized through single-spin s_x rotations. While the majority of the spins in the chain (here drawn in blue) is subjected to imperfect flips around the x axis given by $\pi(1-\epsilon)$, one spin at site index $i=1$ has a differing drive-angle deviation $\epsilon_1=\epsilon'$, resulting in $\pi(1-\epsilon')$ rotations.

periodic flipping of the magnetization of the spin chain with period $2T$, which is twice the original period of the Hamiltonian. Here, we are especially interested in how decreasing the deviation of the rotation angle, ϵ', for a single spin, which we call the metronome spin, affects the dynamics of spatially distant spins at late times. While we set $h_i=0$ in the main text, we also study chains with random fields and disordered couplings in Appendix A and disorder-free chains with the metronome in the center, $\epsilon_{i=\frac{L+1}{2}}=\epsilon'$, in Appendix B.

The stroboscopic evolution of the system, that is, evaluated only once at the beginning of every cycle, is given by the Floquet evolution operator U_F, which propagates the system through one cycle of the Floquet sequence. To gain a better understanding of the stroboscopic dynamics, one would like to find a time-independent Floquet Hamiltonian H_F that generates the Floquet time evolution operator, such that

$$U_F=e^{-iH_x\pi}e^{-iH_{\rm int}t_1}=:e^{-iH_FT}. \tag{2}$$

In most cases, there is no straightforward way to obtain H_F analytically, but one can expand H_F in the so-called Magnus series [46,47]. By construction, H_F is guaranteed to be Hermitian at all orders. We give the first two terms of the expansion,

$$H_F=H_F^{(0)}+H_F^{(1)}+\cdots, \tag{3a}$$

$$H_F^{(0)}=\frac{1}{T}\int_0^T {\rm d}t\,H(t), \tag{3b}$$

$$H_F^{(1)}=\frac{1}{2Ti}\int_0^T {\rm d}t\int_0^t {\rm d}t'\,[H(t),H(t')], \tag{3c}$$

with the first term $H_F^{(0)}$ often being referred to as the average Hamiltonian.