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PAPER

Time crystal embodies chimeralike state in periodically driven quantum spin system

Mahbub Rahaman[1,*], **Akitada Sakurai**[2] and **Analabha Roy**[1,*]

[1] Department of Physics, The University of Burdwan, Burdwan 713104, India
[2] Quantum Information Science and Technology Unit, Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa 904-0495, Japan
[*] Authors to whom any correspondence should be addressed.

E-mail: mrahaman@scholar.buruniv.ac.in and daneel@utexas.edu

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Abstract

Chimera states are a captivating occurrence in which a system composed of multiple interconnected elements exhibits a distinctive combination of synchronized and desynchronized behavior. The emergence of these states can be attributed to the complex interdependence between quantum entanglement and the delicate balance of interactions among system constituents. The emergence of discrete-time crystal (DTC) in typical many-body periodically driven systems occurs when there is a breaking of time translation symmetry. Coexisting coupled DTC and a ferromagnetic dynamically many-body localized (DMBL) phase at distinct regions have been investigated under the controlled spin rotational error of a disorder-free spin-1/2 chain for different types of spin-spin interactions. We contribute a novel approach for the emergence of the DTC-DMBL-chimeralike state, which is robust against external static fields in a periodically driven quantum many-body system.

1. Introduction

The phenomenon of a *chimera state* is observed in coupled systems of identical nonlinear oscillators, when spontaneous synchronized and desynchronized dynamics coexist simultaneously [1, 2]. Kuramoto *et al* first detected this phenomena in a network of non-locally coupled phase oscillators in 2002. Two domains of coherent oscillations with unique frequencies and incoherent oscillations with distributed frequencies were observed. [1]. These patterns were called 'chimera states' by Strogatz [3]. Chimeras have been widely explored in classical systems over the last decade [4–6]. The origin of the chimera lay in the symmetry-breaking bifurcation in the Kuramoto model, which led to a breakdown of global synchronization. This gave rise to a chimera state where spatially distinct regions exhibit different synchronization behaviors [7]. The coexistence of synchronized and desynchronized states in a chimera state can be considered a manifestation of spontaneous symmetry breaking in the context of nonlinear dynamics [8]. In the physical realm, chimera states serve as a possible explanation of unihemispheric slow wave sleep (UHSW) in migrating birds, seals and domestic chicks [9–11]. Chimeras have also been observed in models of electrical power grids, where a synchronous state can be stabilized by tuning the parameters of the generator [12, 13].

Eventually, chimera states were realized in the quantum regime as an ordered phase of matter [14]. However, it has been difficult to extend classical chimeras, which are heavily reliant on nonlinear dynamics, to purely quantum systems with linear unitary dynamics. As a result, quantum chimeras have had to be described in the semi-classical realm. Nonetheless, the possibility of chimeras in closed quantum systems remains, although one needs to take a different approach to create a quantum system where two different dynamics coexist. In fact, states in which two different dynamics coexist in the same quantum system have already been proposed and reported [15–17].

Interest in the formation of chimeras in magnetic systems has recently increased. Curie-Weiss-type models, such as the Ising model [18], are used to represent systems of interacting quantum spins where order