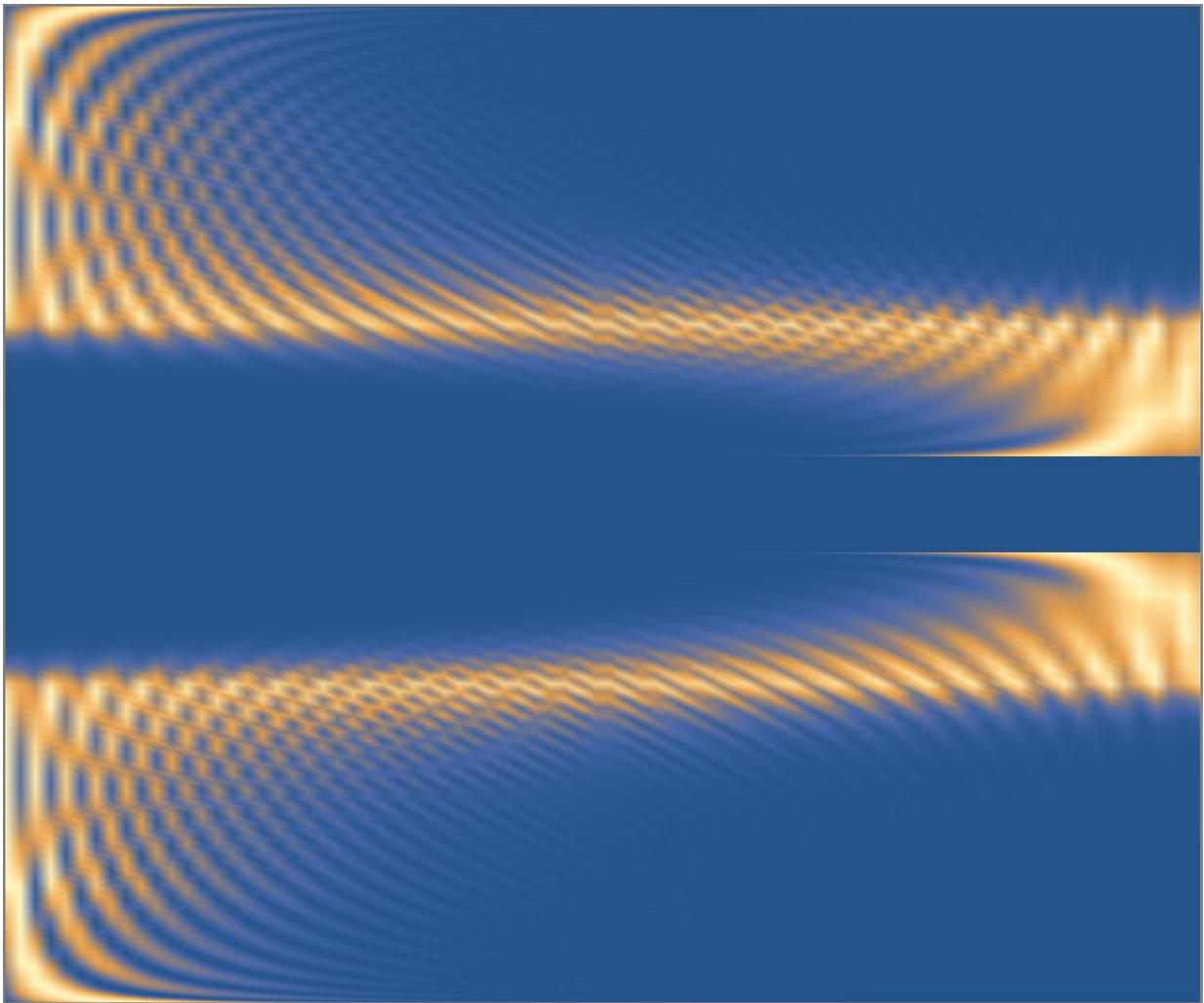# An approach for constructing non-Hermitian topological invariants in real space

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A figure showing the 'bipolar non-Hermitian skin effect '. The approach of topological invariants devised by the researchers is easy to apply even in the presence of this effect. Credit: Song, Yao & Wang.

In physics, non-Hermitian systems are systems that cannot be described by standard (i.e., Hermitian) laws of quantum mechanics, or more precisely, that can only be described by non-Hermitian Hamiltonians. Non-Hermitian systems are ubiquitous in nature. Many open systems, i.e., systems that are not fully isolated from the rest of the world, belong to this class. The topology of these systems (i.e., robust properties that are immune to any changes of parameters) is fundamentally shaped by the so-called "non-Hermitian skin effect," which leads to unconventional bulk-boundary correspondence, which has never been observed in Hermitian systems.

The principle of bulk-boundary correspondence essentially creates a relationship between a bulk property of a material encoded in a topological invariant and what happens at its boundary (e.g., on its surface or edges). To formulate this bulk-boundary correspondence, physicists require a general and computable definition of topological invariants.

So far, most constructions of non-Hermitian topological invariants have been based on a nice geometrical object known as the generalized Brillouin zone (GBZ), which was first introduced last year by a team of researchers at Tsinghua University in China. This calculation, however, can sometimes be very difficult to perform (e.g., for disordered systems), particularly for less experienced scientists.

To overcome this limitation, the same researchers who presented the GBZ calculation have recently come up with a more straightforward and user-friendly construction of topological invariants. They presented this new approach in a paper published in *Physical Review Letters*.

"We take a real-space wavefunction approach, which was stimulated by earlier studies exploring Hermitian systems by Alexei Kitaev and subsequent works by others," Zhong Wang, one of the researchers who

carried out the study, told Phys.org. "At first sight, this real-space approach looks unsuitable for non-Hermitian systems because of the peculiar behavior known as the "non-Hermitian skin effect'" of non-Hermitian systems. But at some point, we realized that it might work even in the presence of non-Hermitian skin effect. Indeed, it does."

The new approach for calculating topological invariants proposed by Wang and his colleagues first entails the calculation of a system's wavefunctions in real space, which is a standard procedure. Once these wavefunctions have been calculated, the non-Hermitian topological invariants can be easily calculated using a series of formulas introduced by the researchers.

A key feature of this new construction proposed by the researchers is that it requires taking the so-called "open-boundary condition." In fact, the periodic boundary condition, which is generally employed when studying Hermitian systems, would lead to invalid results.

"Our study provides a simple approach for non-Hermitian topological invariants, and also deepens our understanding of the non-Hermitian topology," Wang said. "This approach has several advantages. First, it is user-friendly; second, it is widely applicable (e.g., it can be applied to random systems in which the generalized Brillouin zone is not easy to define)."

The simple and intuitive approach introduced by Wang and his colleagues could shed some light on some of the most confusing aspects of non-Hermitian topology and non-Bloch band theory. Their construction also provides convincing evidence that certain peculiar and yet general features of non-Hermitian systems are, in fact, true and natural.

In the future, the theory could have a number of real-world applications.

For instance, it could aid the design of high-quality lasers based on topological ideas.

"We are now working with experimental physicists to bring more non-Hermitian conceptions to reality," Wang said. "Among other efforts, we are investigating the rich many-body physics of non-Hermitian systems, which is currently poorly understood."

More information: Fei Song et al. Non-Hermitian Topological Invariants in Real Space, *Physical Review Letters* (2019). [DOI: 10.1103/PhysRevLett.123.246801](https://doi.org/10.1103/PhysRevLett.123.246801)

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