Interaction driven chiral-symmetry protected exceptional torus in nodal-line semimetals

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Since the theoretical discovery topological insulators, the notion of topology have become much more ubiquitous and further generalized in condensed matter physics such as topological superconductors and topological semimetals. On the other hand, more recent studies have revealed another kind of topological phase in non-equilibrium systems with gain and loss, which are described by a non-Hermitian effective Hamiltonian.

Furthermore such non-Hermitian topological properties can appear even in equilibrium systems due to the life time effects originating from self-energy caused by phonon scattering, Coulomb interaction, impurity scattering, as proposed by Kozii and Fu [1]. For exapmple, if we describe the energy spectrum of quasiparticles having the complex self-energy in terms of effective Hamiltonian, non-Hermitian physics naturally shows up in strongly correlated systems, which is related to gapless defective points called exceptional points. Such exceptional point leads to an open Fermi surface like Fermi arcs in the bulk energy spectrum.

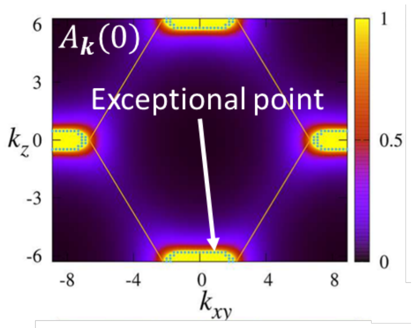

Fig.1 Spectral funtion

To date, various non-Hermitian topological semimetals have been investigated in the previous studies. In addition to the non-Hermitian band touching, an interplay between symmetry and topology leads to the symmetry protected non-Hermitian topological degeneracy. For example, in the two-dimensional chiral symmetric case [2], the exceptional points construct symmetry protected exceptional ring, forming the Fermi plane. In the three dimensional PT symmetric case [3], non-Hermitian NLSMs lead to symmetry protected exceptional surfaces, forming the Fermi volumes. However, the *PT* symmetry does not ensure that such exceptional points emerge at the Fermi level. So, in general situations, exceptional points will not affect the low-energy properties of the system.

In this work, we study the effects of chiral symmetry, which strictly restricts exceptional points to the Fermi level, in NLSMs with strong correlations. We analyze [4] correlated nodal-line semimetals on a diamond lattice Hubbard model with a spatially modulated on-site interaction by using the dynamical mean-field theory and we focus on non-Hermitian properties of the single-particle spectrum. First, we reveal the emergence of a symmetry protected exceptional torus (SPET) unique to non-Hermitian physics with many-body chiral symmetry, which forms the three-dimensional open Fermi surface (Fig.1). Second, we reveal that the static susceptibility for a sublattice with weak interaction is enhanced by the emergence of SPETs.

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[2] T. Yoshida, *et al*., Phys. Rev. B **99**, 121101 (2019).
[3] R. Okugawa and T. Yokoyama, Phys. Rev. B **99**, 041202 (2019).
[4] K. Kimura, T. Yoshida and N. Kawakami, arXiv:1905. 11761 (2019).