Title: Unconventional physics in pseudospin-1 Dirac materials

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Abstract: Quantum materials hosting a flat band, such as pseudospin-1 lattices and magic-angle twisted bilayer graphene, can exhibit drastically new phenomena including unconventional superconductivity, orbital ferromagnetism, and Chern insulating behaviors with topological edge states. These materials are relevant to a variety of physical systems ranging from photonic crystals, optical lattices, two-dimensional electronic lattices and superconducting qutrit to crystalline solids and even bosonic systems. In this talk, two unexpected physical phenomena will be presented: one in massless and another in massive pseudospin-1 Dirac material systems.

The first phenomenon occurs in massless pseudospin-1 wave scattering from a deformed scalar potential domain that generates chaos in the classical limit. Conventionally (e.g., in optics, nonrelativistic quantum mechanics, or relativistic quantum mechanics of spin-1/2 particles), two leaking mechanisms exist: chaos Q-spoiling and Klein tunneling, which make trapping of wave difficult. Surprisingly, we find an energy range in which a pseudospin-1 chaotic cavity is capable of defying both Q-spoiling and super-Klein tunneling. The physical origin of this remarkable phenomenon is a peculiar type of boundary trapping modes that absolutely have no counterpart in nonrelativistic quantum or even in pseudospin-1/2 systems. We uncover an analogy between the long-lived resonant states and surface plasmon modes in optics. The phenomenon can be tested experimentally in emerging electronic or photonic (meta)materials with pseudospin-1 Dirac cones.

The second phenomenon arises in Dirac materials hosting massive pseudospin-1 particles. Specifically, an established principle in the study of topological quantum states in confined systems is the bulk-edge correspondence, which stipulates that band inversion is absolutely necessary for such states to occur. We uncover a striking violation of this principle in pseudospin-1 Dirac materials with a band gap, where the sign of the equivalent mass defines the associated bulk topological invariant. When confining such massive Dirac fermions via a potential with closed boundaries, two distinct situations arise: with or without mass sign change, corresponding to a quantum dot with or without band inversion, respectively. The former case is conventional, where topologically protected chiral edge modes can arise in the gap. For the latter, contrary to the belief that there should be no current-carrying edge channels, we find the emergence of such topological edge states. These states are robust and immune to backscattering. In the presence of a magnetic field, the edge states result in peculiar Fork-Darwin states with respect to Landau-level confinement.

Biography: I earned BS and MS degrees in Optical Engineering from Zhejiang University in 1982 and 1985, and MS and PhD degrees in Physics/Nonlinear Dynamics from University of Maryland, College Park in 1989 and 1992, respectively. Currently I am the ISS Endowed Professor of Electrical Engineering at Arizona State University. I have authored/co-authored about 460 refereed-journal papers and a comprehensive research monograph on Transient Chaos. Honors include a Presidential Early Career Award for Scientists and Engineers (PECASE) from the White House in 1997, election as a Fellow of the American Physical Society in 1999, selection by the Pentagon as a Vannevar Bush Faculty Fellow (class of 2016), and election into the National Academy of Science and Letters of Scotland as a Corresponding Fellow in 2018. My papers have been cited more than 21,000 times (Google-Scholar, H-index 70). My current research interests are nonlinear dynamics, complex networks, physics of Dirac materials, quantum chaos, mathematical biology, data analysis and machine learning.