# Polarizations Underdescribe Vectorial Electromagnetic Waves

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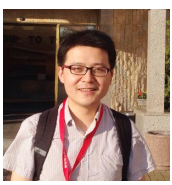
Electromagnetic waves are described by not only polarization ellipses but also cyclically rotating vectors tracing out them. The corresponding fields are respectively directionless steady line fields and directional instantaneous vector fields. Here we study the seminal topic of electromagnetic scattering from the perspective of instantaneous vector fields and uncover how the global topology of the momentum sphere regulates local distributions of tangent scattered fields. Structurally-stable generic singularities of vector fields move cyclically along lines of linear polarizations and at any instant the index sum of all instantaneous singularities has to be the Euler characteristic $\chi$=2. This contrasts sharply with steady line fields, of which generic singularities constrained by the Euler characteristic locate on points of circular polarizations. From such unique perspective of instantaneous singularities, we discovered that for circularly-polarized waves scattered by electromagnetic duality-symmetric particles, since linearly-polarized scatterings are prohibited by helicity conservation, there must exist at least one dark direction along which the scattering is strictly zero. Two such dark directions can be tuned to overlap, along which the scattering would remain zero for arbitrary incident polarizations. We have essentially revealed that *polarizations underdescribe vectorial electromagnetic waves and the instantaneous perspective is indispensable*. The complementarity we discover provides broader and deeper insights into not only electromagnetism, but also other branches of wave physics where singularities are generic and ubiquitous.



**Short Bio:**

**Wei Liu** received his BSc and PhD degrees respectively from Peking University and Australian National University. He works
mainly on Mie theory, and explore its hidden geometric, topological and singular structures.