M2 internship:
Weyl quasiparticles in photonic metamaterials

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Weyl points are discrete points in the first Brillouin zone of a 3D crystal where two bands intersect linearly. In the vicinity of a Weyl point, quasiparticle excitations are called *Weyl fermions*, which are solid-state analogues of relativistic massless particles. Crystals with Weyl points in their band structure typically exhibit chiral edge states localized at the surface of the crystal, which are topologically protected against mixing with bulk states. These materials, known as Weyl semimetals, can therefore exhibit high electron mobilities, which is of great interest for applications in electronics [1].

Weyl semimetals possess photonic analogues, including chiral photonic crystals [2] and metamaterials [3]. These are characterized by a periodic modulation of the refractive index, which obeys specific symmetries. Several intriguing phenomena associated with photonic Weyl points have been reported, including robust surface states and novel electromagnetic scattering laws [4].

Over the past decades, the possibility of controlling the material properties such as electronic transport [5], by coupling relevant transitions between electronic quantum states to the photonic modes of a cavity resonator has attracted significant attention and given rise to a new field of research, known as *polaritonics* [6]. As a natural progression of this field, *topological polaritonics*, which involves coupling a topological electronic system to (topologically trivial) photonic modes is experiencing significant growth [7-9]. It is noteworthy that the potential for coupling topological matter states to topologically nontrivial chiral photonic edge modes that are localized in space has remained largely unexplored. This could pave the way for the discovery of novel topologically-protected electron transport properties.

The objective of this M2 internship is to conduct theoretical investigations using a simple analytical model based on a Hamiltonian formalism [12], with the aim of examining the potential of different experimentally relevant platforms [10, 11] to achieve strong light-matter interactions between a topological electron system and chiral photonic edge modes in the vicinity of an optical Weyl point. These analytical calculations will be complemented by numerical tools, such as finite element and finite-difference time-domain simulations.

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