UIC COLLOQUIUM
Department of Physics

Wednesday, October 23, 2019

“Maxwellian Phases of Matter”

Zubin Jacob

Purdue University

Dirac Matter: Over the last decade the concept of Dirac matter has emerged to the forefront of condensed matter physics. Prominent examples include the physics of the Dirac point in Graphene, Weyl points in topological semi-metals (TaAs) and edge states in topological insulators (Bi_2Te_3). These phases of matter are a playground for studying effects related to the relativistic Dirac equation. We note, however, that they are defined only with respect to the properties of the electron (eg: bandstructure). Therefore, it is still an open question whether Maxwell's equations, which are relativistically invariant similar to the Dirac equation, predict fundamentally new phases of matter. In this talk, we will conclusively answer this question.

Maxwell Matter: We introduce a theoretical framework to search for Maxwellian phases of matter by contrasting the symmetries between the Dirac equation and Maxwell's equations. These underlying symmetries are fundamentally tied to the spin-statistics theorem. In particular, the rigorous definition of photon energy density, photon spin and photon mass inside matter is a long-standing question which is answered by our theory. Using our approach, we predict that there could exist multiple such intriguing phases in nature.

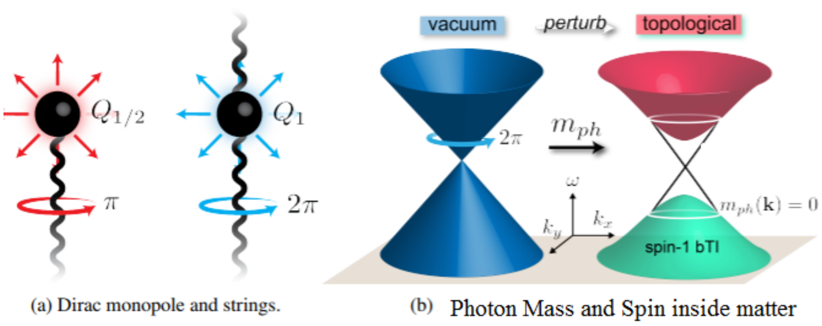

Fig 1: Searching for Maxwellian Phases of Matter

Fundamental Requirement

We show that the fundamental requirement for the existence of Maxwellian phases is non-locality and dispersion in the conductivity tensor of matter ($\overleftrightarrow{\sigma}(\omega, q)$). This requirement can also be understood as arising from the quantum Hall viscosity. Thus the Berry gauge field is induced through a fundamentally new mechanism: the global frequency and momentum dependence of optical response parameters.

Defining Characteristics of Maxwellian Phases of Matter:

1) They possess **Maxwell points**, the spin-1 bosonic counterparts of Weyl points, which can exist in the energy-momentum relationship of electromagnetic waves inside matter.
2) Bulk waves inside such media exhibit gauge invariant Maxwell-Chern-Simons **photon mass** and **photon spin-1 quantization** with three spin projection eigenvalues (m_s=-1, m_s=0, m_s=+1).
3) **Spin-1 edge states** of linearly dispersing photons at the boundary of the Maxwellian phase of matter with completely vanishing electric and magnetic fields on the edge. We emphasize that such a fully transverse electromagnetic edge wave does not exist in any phase of matter known till date.

The Department of Physics Colloquium will be held at 3pm in 238 SES.

**Refreshments will be served from 2:45 pm to 3pm outside of room 238 SES*