T. Sugimoto and **K. Fukutani**
Effects of Rotational-Symmetry Breaking on Physisorption of Ortho- and Para-H_2 on Ag(111), *Phys. Rev. Lett.* **112**, 146101 (2014)

Anisotropic Weyl Fermions from Quasiparticle Excitation Spectrum of a 3D Fulde-Ferrell Superfluid

Weyl fermions were first proposed for describing massless chiral Dirac fermions such as neutrinos in particle physics in 1929. Despite much effort, these fermions have not yet been observed in experiments (neutrinos have mass). Recently, it has been found that the band touching points of single particle energy dispersion in certain solid state materials (named Weyl semimetals) can be described by chiral Weyl equations, thus is equivalent to Weyl fermions. Around these points, the energy dispersions are linear. These points have to appear in pairs with opposite topological invariances and can only be destroyed by merging two points together in sharp contrast to two dimensional Dirac fermions (e.g. graphene) which can be destroyed by breaking time-reversal or spatial inversion symmetries.

The Fulde-Ferrell (FF) superconductor, of which Cooper pairs possess finite center-of-mass momenta, was proposed to be the ground state of a superconductor subject to large Zeeman fields over 50 years ago. However, this elusive state has not been observed conclusively in experiments due to its extremely small parameter regions. Interestingly, a spin-orbit coupling and in-plane Zeeman fields are capable of enhancing the FF superfluids, which dominate the phase diagram. In experiments, the SO coupling and Zeeman field have been created by Raman coupling between atomic hyperfine states and the strength of the Zeeman field may be tuned by the detuning and intensity of Raman lasers. These FF states can support Majorana fermions in 1D and 2D. However, whether such FF superfluids can support Weyl fermion excitations has not been explored.

In this letter, we have studied a 3D Fermi gas with Rashba spin-orbit coupling and in-plane and out-of-plane Zeeman fields. Using mean-field Bogoliubov-de Gennes equations, we have found band touching points in suitable parameter regions between particle and hole branches in the quasiparticle excitation spectrum of a FF superfluid, which possess non-zero topological invariances and anisotropic linear dispersions along all three different directions (shown in Fig. 1(b)), indicating the existence of anisotropic Weyl fermion excitations. The FF superfluids supporting Weyl fermion excitations can be divided into two groups: the gapped FF state (tFF) and gapless FF state (gapless-tFF) as shown in Fig.1 (a), based on whether the minimum of the particle branch of the quasiparticle spectrum except Weyl points is larger than zero. More interestingly, the properties of these Weyl fermions, including their number and position, creation and annihilation, and anisotropy, can be controlled by varying Zeeman fields and interaction strength between atoms.

Finally, we have studied the signature of anisotropic Weyl fermion excitations in the speeds of sound of the FF fermionic superfluids and found anisotropic sound speeds with a minimum at the topological phase transition point, reflecting the existence of Weyl fermion excitations in a FF superfluid. The sound speeds are measurable in experiments.

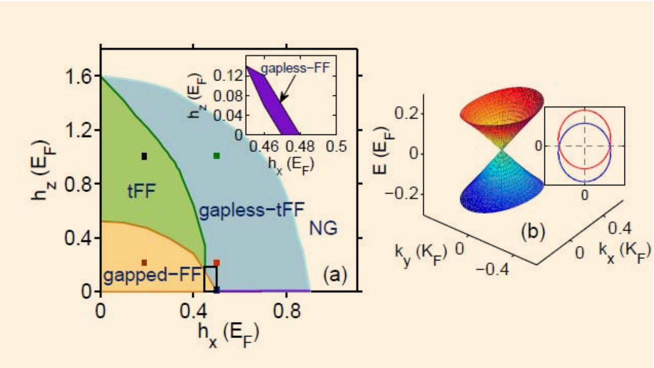

Fig.1 (a) Mean-field phase diagrams of 3D spin-orbit coupled Fermi gases. (b) Quasiparticle excitations spectrum around a Weyl point.

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Is Emergent Universe a consequence of Particle Creation Process?

The proposed cosmological scenarios to overcome the challenging issue: the initial singularity (Big Bang) of standard cosmology can be classified as bouncing universes or emergent universes. The present article focuses on the second choice which arises due to the search for singularity free solutions in the context of classical general relativity. Briefly, an emergent universe is a model universe in which there is no time-like singularity, ever existing and having almost static behavior in the infinite past ($t \to -\infty$). Also, emergent universe scenario can be considered as an extended modern version of the original Lemaitre—Eddington universe.

The article deals with universe as a non-equilibrium