Pilkyung Moon[1]

Mikito Koshino[2], Young-Woo Son[3]

[1]New York University Shanghai, Shanghai, China,
[2]Osaka University, Toyonaka, Japan, [3]Korea Institute of Advanced Study, Seoul, Korea

pilkyung.moon@nyu.edu

Theory of Dirac Electrons in a Dodecagonal Graphene Quasicrystal

Quantum states of quasiparticles in solids are dictated by symmetry. Quasicrystals, which can have quasiperiodic orders (such as rotational symmetry) without spatial periodicity, have been used to study quantum states between the limits of periodic order and disorder. The study of the influence of quasiperiodic order has focused on extended wave functions of ordered states, pseudogaps, and fine structures of density of states. However, these studies have been limited to nonrelativistic fermions.

Recently, we reported that a relativistic Dirac fermion quasicrystal can be realized when the Dirac electrons in a single-layer graphene are incommensurately modulated by another single-layer graphene which is rotated by an exact 30° [1].

When two-dimensional atomic layers are stacked incommensurately, the interference between the two lattice arrangement leads to new order to the system. For example, the incommensurate stack of two graphene layers at a rotation angle other than 0 and 30° exhibits an extra periodicity in the form of moiré pattern (aka twisted bilayer graphene) [2]. The physical properties of twisted bilayer graphene are well described by the effective theory based on the moiré interference period [3-5]. However, such moiré periodicity disappears at a rotation angle of 30°, since the structure gains a 12-fold rotational symmetry which is not compatible with a translation. Mathematically, it is known that two honeycomb structures overlaid at 30° form a dodecagonal quasicrystal [6].

In this talk, I will discuss the theory of Dirac electrons in a dodecagonal graphene quasicrystal. I will first explain the emergence of the infinite number of Dirac cone replicas in ARPES in terms of the generalized Umklapp scattering. The contribution of multiple scattering to the unusually strong scattering signals associated with long wave vectors will be emphasized as well. In addition, I will show that the configuration of the Dirac cone replicas near the Γ point provides a solid evidence of the rotation angle at an exact 30° [1].
Moreover, I will report a rigorous effective model to describe the electronic structures of the graphene quasicrystal and show that very unique features, such as the neither localized nor extended states (aka critical states), arise in this system [7].

References

[1] S. J. Ahn,* P. Moon,* T.-H. Kim,* H.-W. Kim, H.C. Shin, E. H. Kim, H. W. Cha, S.-J. Kahng, P. Kim, M. Koshino, Y.-W. Son,† C.-W. Yang,† and J. R. Ahn,† Science 361, 782 (2018) (*: co-first authors, †: co-corresponding authors).
[2] C. Berger et al., Science 312, 1191 (2006).
[3] J. M. B. Lopes dos Santos, N. M. R. Peres, and A. H. Castro Neto, Phys. Rev. Lett. 99, 256802 (2007).
[4] P. Moon and M. Koshino, Phys. Rev. B 85, 195458 (2012).
[5] P. Moon and M. Koshino, Phys. Rev. B 87, 205404 (2013).
[6] P. Stampfli, Helv. Phys. Acta 59, 1260 (1986).
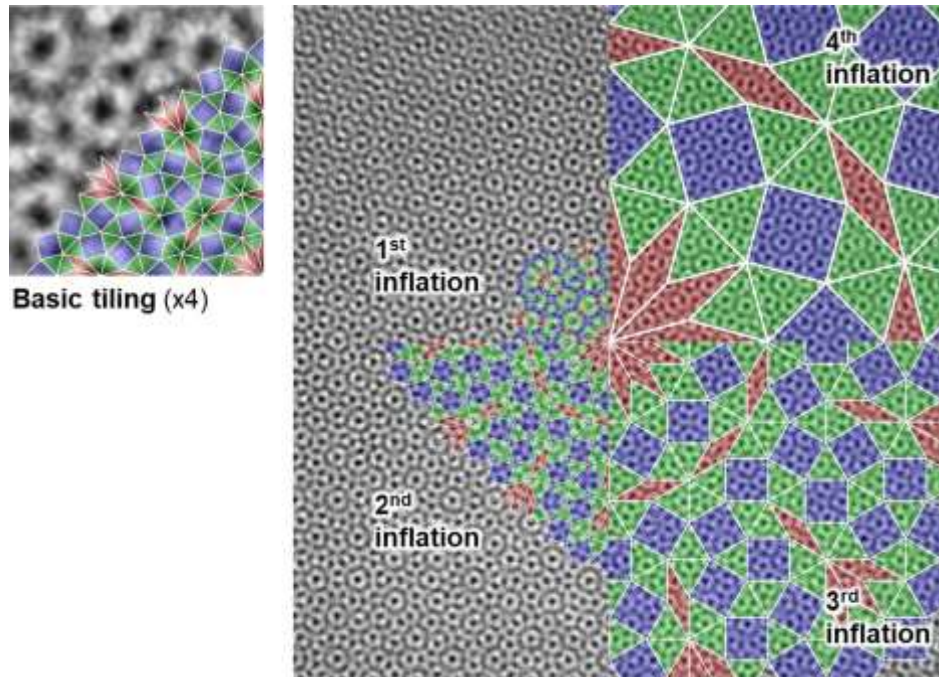[7] P. Moon, M. Koshino, and Y.-W. Son (in preparation).

Figures

Basic tiling (x4)

Figure 1: Color-coded dodecagonal tiling of the TEM image of a graphene quasicrystal [1].
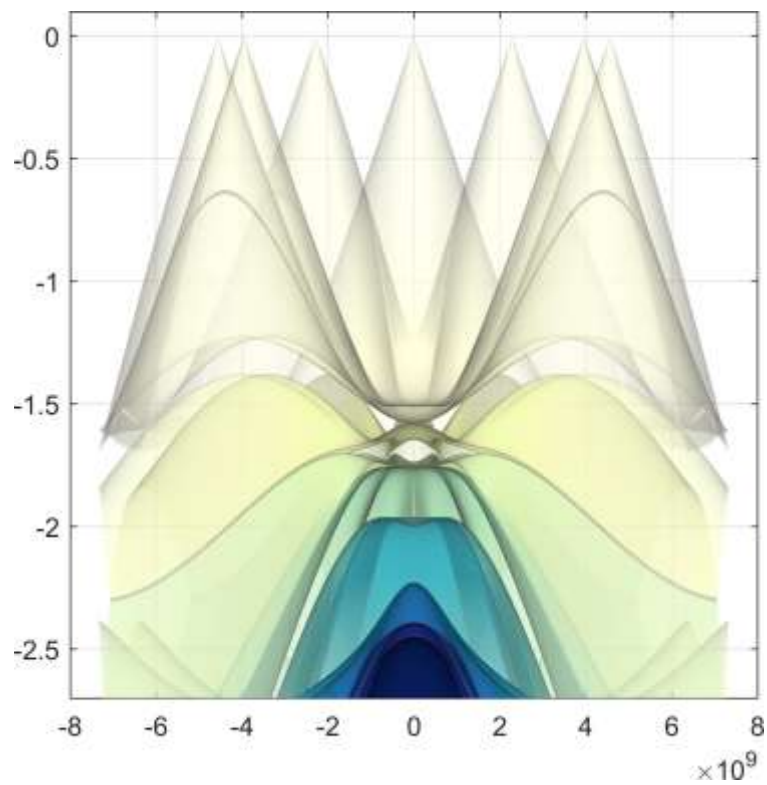

Figure 2: Electronic structures of a graphene quasicrystal calculated by the effective model [7].