Quasiperiodic systems and appearance of the fractal structure in continuous phase transitions

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Quasicrystals, due to recent discoveries, attract a lot of attractions. In these systems, one encounters similar patterns, whereas translational symmetry is completely absent. In quasicrystal structures, one can classify vertices based on similar patterns. In this seminar, I will discuss how this classification may induce fractality near second-order phase transitions. For this purpose, I examine the Bose-Hubbard model in the Penrose lattice based on inhomogeneous mean-field theory. Since the averaged coordination number in the Penrose lattice is four, the mean-field phase diagram consisting of the Mott insulator (MI) and superfluid (SF) phase is similar to that of the square lattice. However, the spatial distribution of Bose condensate in the SF phase is significantly different from the uniform distribution in the square lattice. We find a fractal structure in its distribution near the MI-SF phase boundary. The emergence of the fractal structure is a consequence of the cooperative effect between quasiperiodicity in the Penrose lattice and criticality at the phase transition. Then, I will return to the simpler case, 2D Ising model, and show a similar fractal structure in the phase transition. We also investigate this system with the Monte-Carlo simulation.

References:

[1] R. Ghadimi, T. Sugimoto, and T. Tohyama, arXiv:2005.04885.