DESCRIPTION FOR THE GENERAL PUBLIC

One of the physics problem is to understand why at sufficiently low temperatures macroscopic bodies form crystals? A typical example is a transition of liquid water to ice cubes at a freezing temperature. A fundamental law of physics states that at sufficiently low temperatures, configurations of interacting particles minimize the energy of the system – such configurations are called ground states. The above crystal problem can be then formulated mathematically in the following way: Why ground states of systems of many interacting particles are spatially periodic, like for example cubic crystals of kitchen salt?

It has been an assumption (never proved) of solid-state physics. Then in 1982, Dan Shechtman provided an experimental counterexample. He discovered a certain metallic alloy which does not form any crystallographic lattice; for this revolutionary discovery he received a Nobel Prize in Chemistry in 2011.

In this project we will consider classical lattice-gas models, where particles occupy vertices of the periodic square or cubic lattice, non-periodic are ground-state assignments of particles to lattice sites. We will study stability of such non-periodic ground states with respect to random thermal motions. The main research task of the project is a construction of a lattice-gas model with nearest-neighbor interactions, with a non-period ground state stable low temperatures. It would be a first microscopic model of a quasicrystal.

Our constructions will be based on non-periodic tilings. A problem of the existence of non-periodic tilings appeared in 1900 in one of the problems posed by David Hilbert, one of the greatest mathematicians. The second part of the 18-th problem can be stated in the following way: Does there exist a polygon which can tile the plane but only in a non-periodic way? Since then, there were constructed many sets of tiles which tile the plane in only non-periodic way; the most famous one is a set of two tiles, a kite and a dart due to Roger Penrose.

In our research project we address the fundamental question: How the global (non-periodic) order arises from local rules? Our research tasks are at the interface between several fields: solid-state physics of quasicrystals, tilings, symbolic dynamical systems, probability, and noise-resilience in computer science.