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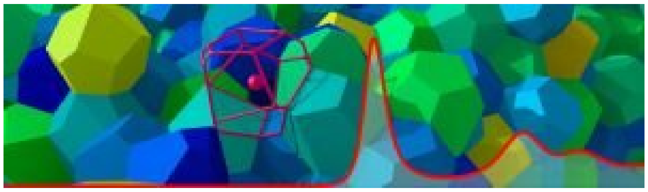
Order hidden in disorder

April 3 2019, by Monika Landgraf



No matter how disordered a system may be initially – individual optimization of each cell gradually results in the formation of the same structure with a hidden order. Credit: Michael A. Klatt

Partitioning space into cells with optimum geometrical properties is a central challenge in many fields of science and technology. Researchers of Karlsruhe Institute of Technology (KIT) and colleagues from several countries have now found that in amorphous, i.e. disordered, systems, optimization of the individual cells gradually results in the same structure, although it remains amorphous. The disordered structure quickly converges to hyperuniformity, a hidden order on large scales. This is reported in *Nature Communications*.

Science research often entails the search for an optimum foam or for a method to pack spheres as closely as possible. The ideal tessellation of three-dimensional space has been studied for a long time by scientists. It is not only of theoretical interest, but relevant to many practical applications, among others for telecommunications, image processing, or complex granules. Researchers of KIT's Institute of Stochastics have now studied a special problem of tessellation, the quantizer problem.

"The goal is to partition space into cells, and all points in a cell to be located as closely as possible to the cell center, intuitively speaking," says Dr. Michael Andreas Klatt, former staff member of the Institute, who now works at Princeton University in the U.S. Solutions of the quantizer problem can be used for the development of novel materials and may contribute to a better understanding of the unique properties of complex cell tissue in future.

The theoretical work combines methods of stochastic geometry and statistical physics, and is now reported in *Nature Communications*. The researchers of KIT, Princeton University, Friedrich-Alexander-Universität (FAU) Erlangen-Nuremberg, Ruđer Bošković Institute in Zagreb, and Murdoch University in Perth used the so-called Lloyd algorithm, a method to partition space into uniform regions. Every region has exactly one center and contains those points in space that are closer to this than to any other center. Such regions are referred to as Voronoi cells. The Voronoi diagram is made up of all points having more than one closest center and, hence, forming the boundaries of the regions.

The scientists studied stepwise local optimization of various point patterns and found that all completely amorphous, i.e. disordered, states do not only remain completely amorphous, but that the initially diverse processes converge to a statistically indistinguishable ensemble. Stepwise local optimization also rapidly compensates extreme global fluctuations of density. "The resulting structure is nearly hyperuniform. It does not exhibit any obvious, but a hidden order on large scales," Klatt says.

Hence, this order hidden in amorphous systems is universal, i.e. stable and independent of properties of the initial state. This provides basic insight into the interaction of order and disorder and can be used among others for the development of novel materials. Of particular interest are photonic metamaterials similar to a semiconductor for light or so-called block copolymers, i.e. nanoparticles composed of longer sequences or blocks of various molecules that form regular and complex structures in a self-organized way.

More information: Michael A. Klatt et al. Universal hidden order in amorphous cellular geometries, *Nature Communications* (2019). DOI: 10.1038/s41467-019-08360-5

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