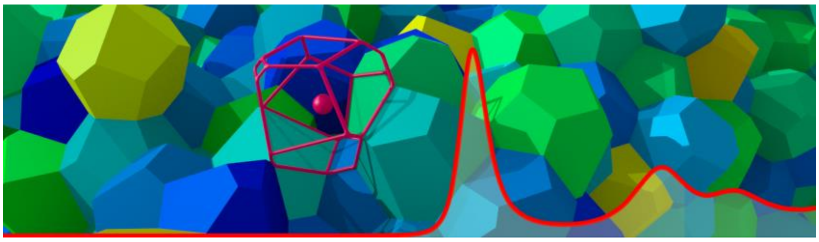
Order Hidden in Disorder

Convergence to Hyperuniformity in Amorphous Systems Can Be Used to Develop Novel Materials and Study Cell Tissue – Publication in *Nature Communications*



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. (Figure: 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*. (DOI: 10.1038/s41467-019-08360-5)

No matter whether you search for an optimum foam or for a method to pack spheres as closely as possible – ideal tessellation of three-dimensional space, that means complete partitioning into cells with special geometrical properties, 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

Monika Landgraf
Chief Press Officer,
Head of Corp. Communications

Kaiserstraße 12
76131 Karlsruhe, Germany
Phone: +49 721 608-21105
Email: presse@kit.edu

Press contact:

Kosta Schinarakis
Press Officer
Phone: +49 721 608-21165
Email: schinarakis@kit.edu

Additional materials:

Publication in *Nature Communications:*

https://www.nature.com/articles/s41467-019-08360-5

Related animation:

https://drive.google.com/open?id=1f0b0dfxanFF-bABWt_xmXHxyEdaCNmGJH

USA. 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 that combines methods of stochastic geometry and statistical physics 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.

The work reported in *Nature Communications* was carried out by the research group “Geometry & Physics of Spatial Random Systems” funded by the German Research Foundation (DFG). The interdisciplinary team consists of groups of KIT, FAU, and the University of Aarhus (Denmark) with experts in stochastic geometry, spatial statistics, and statistical physics, among others. Publication of the work was funded by the KIT publication fund.

Original publication (open access):

Michael A. Klatt, Jakov Lovrić, Duyu Chen, Sebastian C. Kapfer, Fabian M. Schaller, Philipp W. A. Schönhöfer, Bruce S. Gardiner, Ana-

Sunčana Smith, Gerd E. Schröder-Turk & Salvatore Torquato: Universal hidden order in amorphous cellular geometries. Nature Communications, 2019. (DOI: 10.1038/s41467-019-08360-5)

Animation relating to the publication:

https://drive.google.com/open?id=1f0b0dfxanFFbABWt_xmXHxyE-daCNmGJH

Being "The Research University in the Helmholtz Association," KIT creates and imparts knowledge for the society and the environment. It is the objective to make significant contributions to the global challenges in the fields of energy, mobility and information. For this, about 9,300 employees cooperate in a broad range of disciplines in natural sciences, engineering sciences, economics, and the humanities and social sciences. KIT prepares its 25,100 students for responsible tasks in society, industry, and science by offering research-based study programs. Innovation efforts at KIT build a bridge between important scientific findings and their application for the benefit of society, economic prosperity, and the preservation of our natural basis of life.

This press release is available on the internet at http://www.sek.kit.edu/english/press_office.php.

The photo in the best quality available to us may be downloaded under www.kit.edu or requested by mail to presse@kit.edu or phone +49 721 608-21105. The photo may be used in the context given above exclusively.

This year's **anniversary logo** recalls the milestones reached by KIT and its long tradition in research, teaching, and innovation. On October 1, 2009, KIT was established by the merger of its two predecessor institutions: the Polytechnic School and later University of Karlsruhe was founded in 1825, the Nuclear Reactor Construction and Operation Company and later Karlsruhe Research Center in 1956.