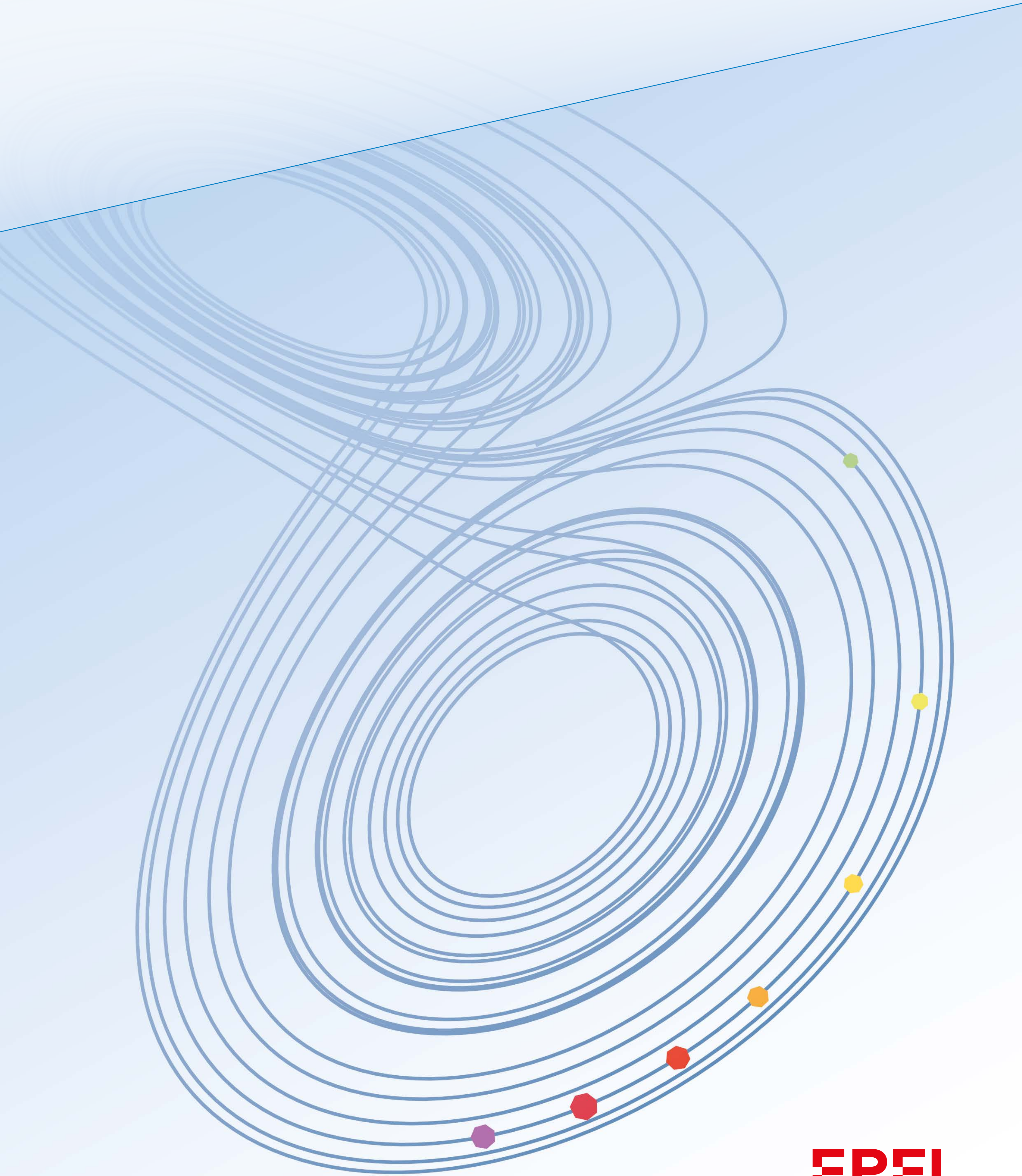
DOCTORAL
SCHOOL

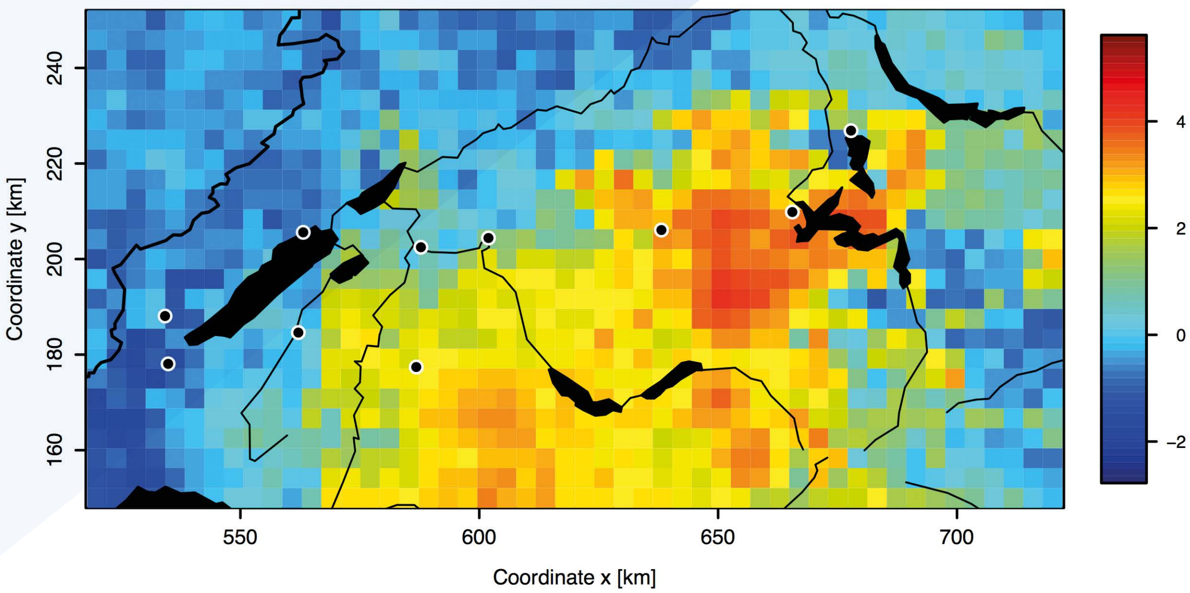
MATHEMATICS



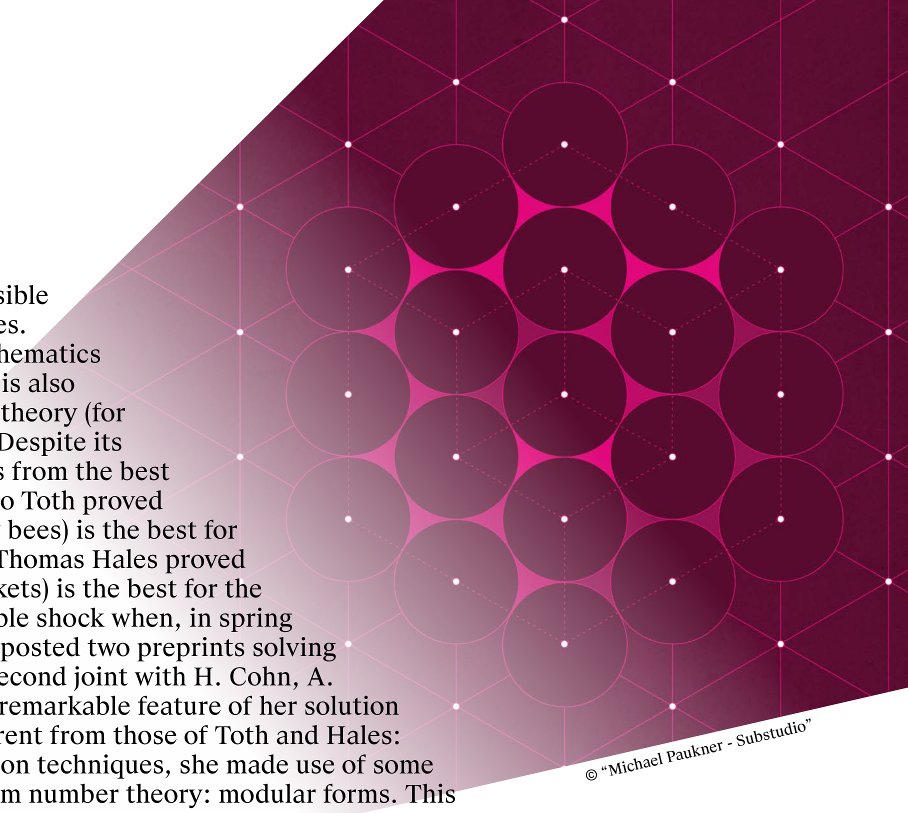
EPFL

Activities in the doctoral program in Mathematics span a broad spectrum, from fundamental research in algebra, analysis, geometry, probability and topology to concrete applications of numerical analysis, optimization and statistics. Interdisciplinary projects capitalizing on synergies with other EPFL doctoral programs are encouraged.

Risk is inescapable, but often it is important to estimate it as well as possible. Insurance companies must gauge risks accurately in order to set premiums, banks must understand their exposure to shocks in financial markets, and public authorities must estimate the likely scale of floods and other disasters when determining planning regulations. Accurate estimation of risk involves extrapolation from observed past events to possible future ones, using statistical modeling to fit stochastic models suitable for rare events. Such models involve Poisson point processes, regular variation, stochastic processes on general spaces and random sets, and their estimation requires advanced ideas from modern statistics. Recent applications include estimation of the size and extent of future heat waves or cold snaps, space-time modeling of extreme rainfall and snowfall, probabilities of joint flooding at points on a river network, risk to power stations from windstorms and lightning strikes, and applications in finance.



Sphere packing solved in higher dimensions



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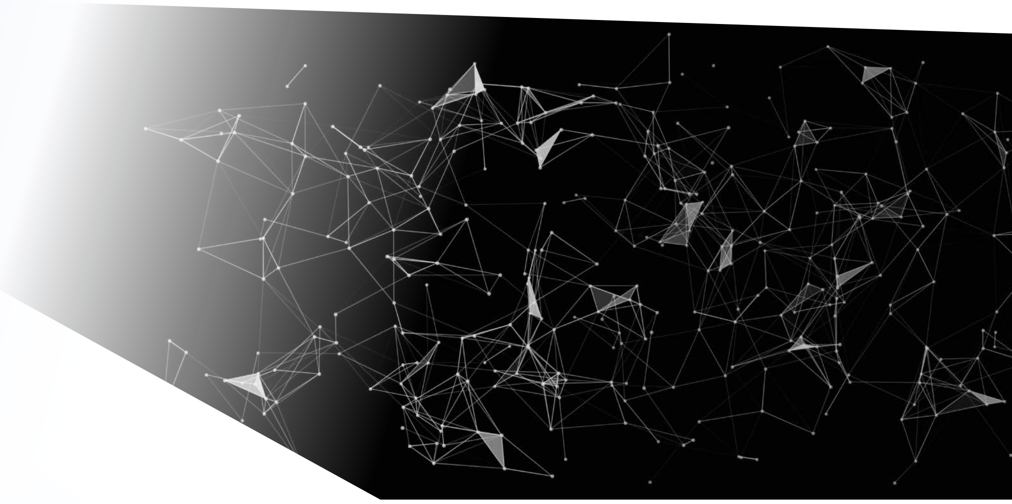
The sphere packing problem asks for the best possible way to fill an euclidean space with identical spheres. This is one of the most venerable problems in mathematics going back to L. Euler and J. Kepler. The problem is also of practical importance, especially in information theory (for instance to build optimal error correcting codes). Despite its innocuous aspect, the problem has resisted efforts from the best minds for centuries: it is only in the 50’s that Lazlo Toth proved that the “honeycomb” packing (the one created by bees) is the best for the plane and at the end of the 20th century that Thomas Hales proved that the “orange packing” (the one in farmers markets) is the best for the 3-dimensional space. It was therefore a considerable shock when, in spring 2016, Maryna Viazovska (then Postdoc in Berlin), posted two preprints solving the problem in dimension 8 and 24 (the second joint with H. Cohn, A. Kumar, S. Miller and D. Radchenko). A remarkable feature of her solution is that her methods are entirely different from those of Toth and Hales: instead of combinatorial optimization techniques, she made use of some of the most important objects from number theory: modular forms. This groundbreaking work earned Maryna Viazovska, now holding the Chair of Number Theory at EPFL, a number of honors: invited lectures series in the best universities worldwide, invited speaker at the 2018 International Congress of Mathematicians and a number of international prizes including the 2017 Clay Research Award and SASTRA Ramanujan Prize, the 2018 New Horizon Prize in Mathematics, the 2019 Fermat Prize and the 2020 EMS Prize.



How does the structure of the brain shape its functions?

At the Laboratory of Topology and Neuroscience I am developing new mathematical theories to answer one of the most fascinating question in neuroscience: how does the structure of the brain shape its functions? In collaboration with the neuroscientists from the Blue Brain Project, we are using algebraic topology to analyze the architecture of the brain, which is formed by billions of neural connections. The structure of those neural connections and the patterns generated by neural activities form incredibly rich and complex networks. The sophisticated theory of algebraic topology provides us with a powerful framework to quantitatively describe both the function and the shape of these networks. For instance, by turning the neural networks into simplicial complexes, a higher-dimensional version of graphs, we quantify their complexity by the presence of higher-dimensional structures, such as cycles or cavities. These structures are believed to play a crucial role in the information flow in the brain. In parallel, my research focuses on developing signal processing techniques based on notions from algebraic topology.

Together with Prof. Vandergheynst’s Signal Processing laboratory, we are extending the theory of signal processing on graphs to simplicial complexes, with applications that range from neuroscience to reconstruction of meshes.

Stefania Ebli,
PhD student at the Laboratory for Topology and Neuroscience

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Program requirements and application

A Master’s degree or an equivalent title in mathematics, physics, computer science, or related fields is required of all applicants.
Application deadline: Changes to the application deadlines may apply. For the most recent information, please refer to the program’s webpage.
phd.epfl.ch/application

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