MATHEMATICS

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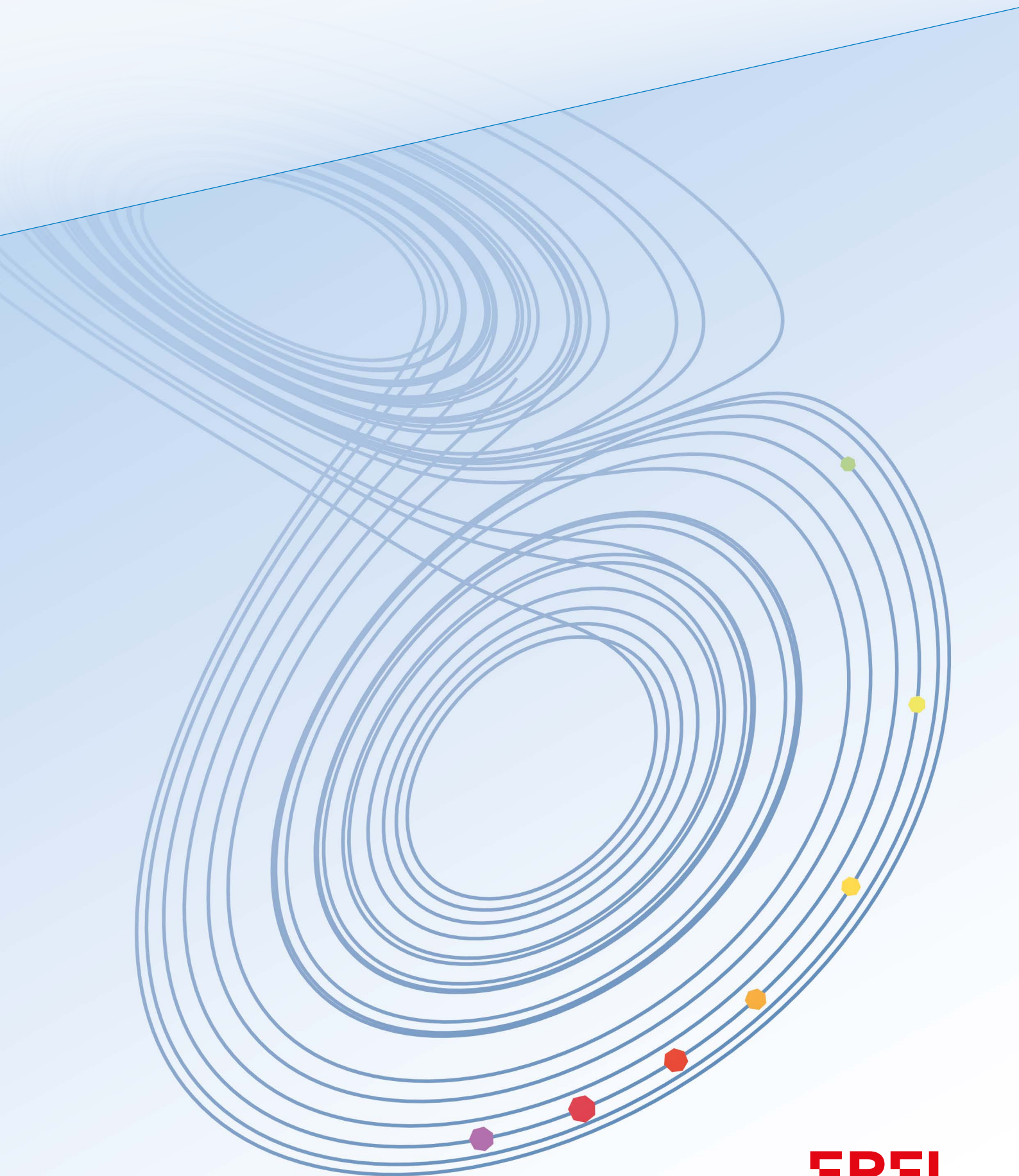
Activity in the doctoral program in mathematics spans a broad spectrum, from fundamental research in algebra, analysis, geometry, probability and topology to concrete applications of numerical analysis, optimization and statistics. Interdisciplinary projects capitalizing on synergies with other EPFL 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.
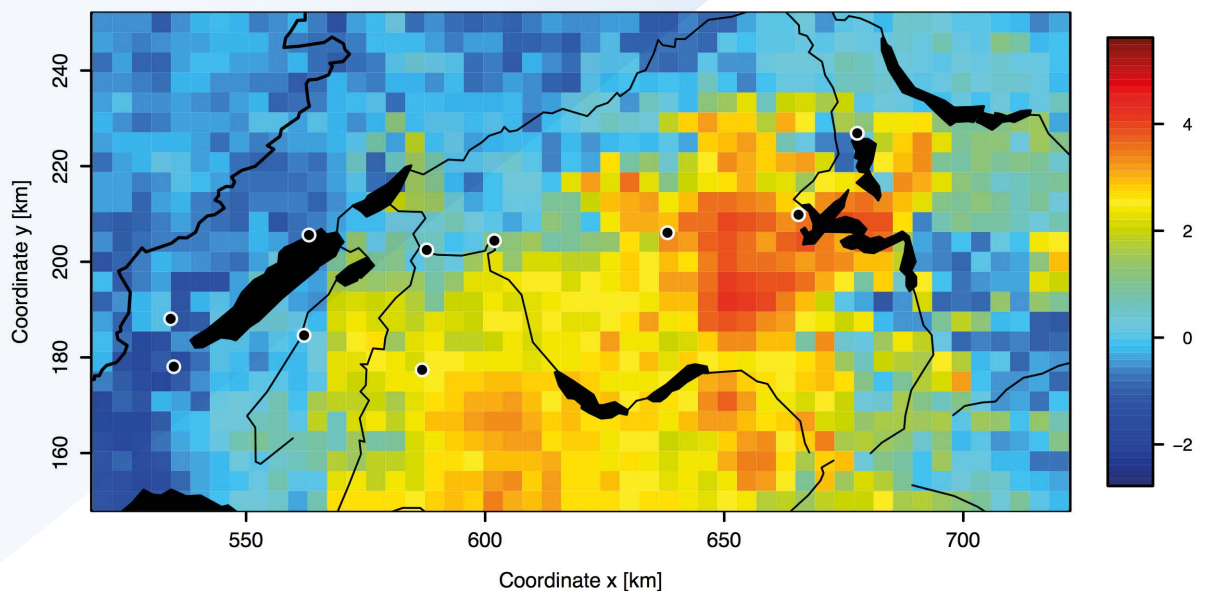
Sphere Packing Solved in Higher Dimensions

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 the 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 (who now holds the
Chair of Number Theory at EPFL) a number of honors: invited lectures
series in the best universities worldwide, an invitation to speak at
the 2018 International Congress of Mathematicians and a number of
international prizes including the 2018 New Horizon Prize in Mathematics.

Prof. Michel about Prof. Viazovska's research

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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 analyzing 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

A master's degree or an equivalent title in mathematics, physics, computer science, or related fields is required of all applicants.
phd.epfl.ch/application

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