

Foreword



Distribution, a major trend in computing over the last decade, affects the way we perform computation in several ways: microprocessor architectures are now multi-core, offering several parallel threads of computation, while large-scale systems distribute storage and computation across several processors, servers, or data centers. To be efficient, software now has to scale, that is, improve its performance when more computation nodes are available. My research is focused on answering fundamental questions in distributed computing, and on transforming these insights into working systems.

After obtaining a double degree in mathematics and computer science, I did my PhD in distributed computing at EPFL, researching the interplay between randomness and efficient distributed computation. Afterwards, I moved to MIT, where I applied some of these ideas to practical concurrent data structures, and then spent some time as a researcher at Microsoft Research Cambridge, as well as ETH Zurich.

One of the main things that stayed with me after my interview visit at IST Austria was that everyone I met was excellent in their respective field. As such, I think the Institute has a unique mix of breadth across different topics, but also great depth in each of the fields. Since starting in December 2017, I have been trying to get acquainted with IST Austria, and to learn more about research outside of my area. I am really excited to join this unique community, and look forward to collaborating with my new colleagues.

Dan Alistarh | Assistant Professor, IST Austria



Commitment confirmed to expand world-class research at IST Austria

Federal Minister Heinz Faßmann and Governor of Lower Austria Johanna Mikl-Leitner confirmed their commitment to support IST Austria against the background that the performance agreement for the period 2018–2020 has been signed. For the next three years, IST Austria will have 219 million euros at its disposal.

“IST Austria is a beacon project of excellence that contributes to increase Austria’s visibility on the international research map. IST Austria opened ten years ago and has since achieved considerable success. Today we are starting the second ten-year development phase. As stated in the 15a agreement, a total of 1.35 billion euros will be provided, with 988 million euros coming from the federal government. We will thus invest in research infrastructure and double the number of researchers. That will also strengthen Austria as a research and innovation hub and support IST Austria on its way to the top”, stated Heinz Faßmann.



Two ERC Consolidator Grants awarded to IST Austria professors

Grants from the European Research Council (ERC) are considered gold medals of research in Europe, given the stiff competition and exacting standards applied in the selection process. In the last round of awards, Professors Sylvia Cremer and Fyodor Kondrashov received Consolidator Grants, increasing the total number of ERC Grants at IST Austria to 37.

President Tom Henzinger states: “The two additional Consolidator Grants prove once again that our scientists perform cutting-edge research on the highest level. The fact that both grantees work in the field of evolutionary biology shows that this field is well established at IST Austria.”

Sylvia Cremer is interested in behavioral ecology and evolutionary immunology in ant societies, and has led a research group at IST Austria since 2010. Fyodor Kondrashov is investigating evolutionary genomics. His ERC grant has been transferred from his previous institution in Spain to IST Austria.

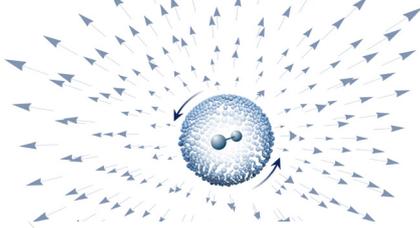


New project to investigate role of novel protein in cancer metastasis

Metastasis is responsible for 90% of deaths from tumors. It is the greatest challenge to a cancer patient’s survival. Metastatic spread occurs in several stages; at one point, tumor cells become mobile and cross into and out of blood vessels. How these stages are controlled is not yet fully understood, but a deeper understanding could lead to new treatments.

The Siekhaus Group will investigate the role of a recently discovered protein in metastasis. They previously identified a protein in the fruitfly *Drosophila* that could play a role in metastasis. In cooperation with two researchers at the Karl Landsteiner University for Health Sciences, they will seek to understand its role in mice and human tissue.

Their project is funded by the NÖ Forschungs- und Bildungsges.m.b.H. The grants serve to strengthen research competence and the connections between research institutes located in Lower Austria.



New manifestation of magnetic monopoles discovered

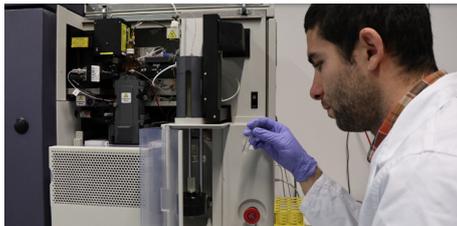
The startling similarity between the physical laws describing electric phenomena and those describing magnetic phenomena has been known since the 19th century. However, the one piece that would make the two perfectly symmetric was missing: magnetic monopoles. While magnetic monopoles in the form of elementary particles remain elusive,

there have been some recent successes in engineering objects that behave effectively like magnetic monopoles. Now, IST Austria scientists have shown in a *Physical Review Letters* paper that there is a much simpler way to observe such magnetic monopoles: they have demonstrated that superfluid helium droplets act as magnetic monopoles from the perspective of molecules that are immersed inside them.

Nanometer-sized drops of superfluid helium with molecules immersed in them have been studied for several decades already, and it is one of the systems that Mikhail Lemeshko and Enderalp Yakaboylu are particularly interested in. Previously, Lemeshko proposed a new quasiparticle that drastically simplifies the mathematical description

of such rotating molecules, and showed that this quasiparticle, the angulon, can explain observations that had been collected over 20 years. Yakaboylu used the angulon to predict previously unknown properties of these systems. The property in superfluid helium droplets that they have now discovered, however, came unexpectedly—and only after they had exchanged ideas with mathematician Andreas Deuchert. Such collaborations are not unusual at IST Austria, where interaction between research groups of different fields is fostered.

According to the researchers, the discovery opens up new possibilities for studying magnetic monopoles. The appearance of magnetic monopoles in superfluid helium droplets is very different from the other, previously studied, systems.



More complex biological systems evolve more freely

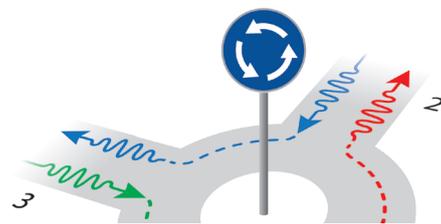
The genotype determines the phenotype. Evolution acts on changes in the phenotype, which occur when mutations change the underlying genotype. But what changes to the phenotype can be produced by mutations is not without bounds. However, IST Austria researchers found that in a gene regulatory system in the bacterium *Escherichia coli*,

the more components that are mutated, the more freely the system can evolve. This is the result of a study published by a team led by Calin Guet and Jonathan Bollback, with first author postdoc Mato Lagator, in *eLife*.

The effects of mutations define how a system can change. But when we take a system composed of several components, such as a system that regulates gene expression, what happens when not only a single component is mutated, but several? The researchers studied this question in a small gene regulatory system in *E. coli* that consists of two components: a transcription factor, which is a protein that controls the rate of transcription of genetic information from DNA to RNA; and its binding site on the DNA, where the transcription factor binds to

start transcription. By mutating each component on its own, and then mutating both components at the same time, they found that the system's evolution is less limited when more components are mutated.

The team then looked at why the system can evolve in more directions, compared to its individual components. They found that the system evolves more freely because mutations in the two components interact with each other, a phenomenon they call "intermolecular epistasis". So far, our understanding of epistasis has mostly been descriptive, and how the existing molecular mechanisms define the patterns of epistasis had not been understood. In their study, the researchers provide a mechanistic understanding of how the mutations in two different molecules interact.



Quantum computer component downsized by two orders of magnitude

Qubits, or quantum bits, are the key building blocks that lie at the heart of every quantum computer. In order to perform a computation, signals need to be directed to and from qubits. These qubits are extremely sensitive to interference from their environment, and need to be shielded from unwanted signals, in particular from magnetic fields. It is thus a

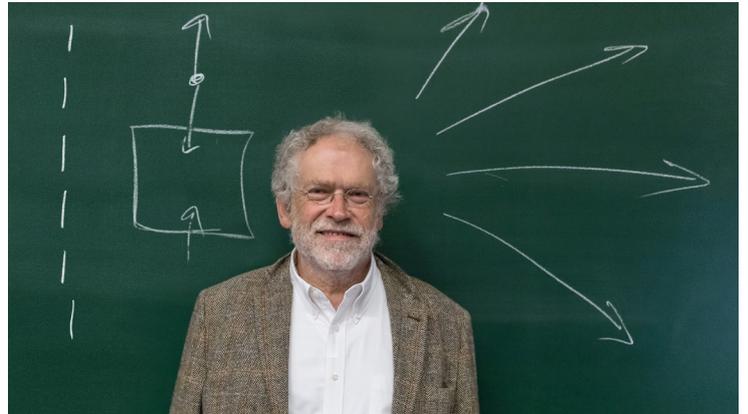
serious problem that the devices built to shield qubits from unwanted signals, known as nonreciprocal devices, are themselves producing magnetic fields. Moreover, they are several centimeters in size. Now, IST Austria scientists, simultaneously with researchers in Switzerland and the United States, have decreased the size of nonreciprocal devices by two orders of magnitude. Their device, whose function they compare to that of a traffic roundabout for photons, is only about a tenth of a millimeter in size, and it is not magnetic. Their study was published in the open access journal *Nature Communications*.

The 'roundabouts' that Johannes Fink and Shabir Barzanjeh have designed consist of aluminum circuits on a silicon chip, and are the first to be based

on micromechanical oscillators: two small silicon beams oscillate on the chip like the strings of a guitar and interact with the electrical circuit. These devices are tiny in size, one of the major advantages the new component has over its traditional predecessors, which were a few centimeters wide. Currently, only a few qubits have been used to test the principles of quantum computers, but in the future, thousands or even millions of qubits will be connected together, and many of these qubits will require their own circulator. Yet some hurdles need to be overcome before the devices can be used for this specific application. For example, the available signal bandwidth is currently still quite small, and the required drive powers might harm the qubits. However, the researchers are confident that these problems will turn out to be solvable.

IST Lecture by Quantum Physicist Anton Zeilinger

On March 13, Anton Zeilinger will speak about “Quantum Communication”. After more than two decades of research, quantum communication has now reached a rather advanced level. Zeilinger will give an overview of the current state with a focus on quantum communication with individual photons. Early experiments have confirmed that unconditionally secure quantum cryptography is possible. The most recent experiments included long-distance quantum teleportation. All these developments clearly point towards a future quantum internet. Zeilinger is a professor of physics at the University of Vienna, group leader at the Institute for Quantum Optics and Quantum Information, and president of the Austrian Academy of Sciences.



For information and registration visit our [website](#).



Science Outreach Activities 2018

This year, IST Austria will host two science festivals and two science camps for children on campus. The “Lange Nacht der Forschung” on April 13 will give visitors the opportunity to find out more about the research conducted by scientific institutions from Lower Austria. Open Campus on May 27 will allow adults and children eager for knowledge to explore science in a hands-on exhibition, go on campus and laboratory tours, and take part in a diverse children’s program. The “Sommercampus” on August 20-24 will encourage primary school children to engage in science and art. Last but not least, “Top Models in Science” on August 27-29 will teach teenagers how to use mathematical and computer models.

For further information view our [website](#).

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Jean-Michel Raimond, Kastler Brossel Laboratory (Dec 4) | Cosma Shalizi, Carnegie Mellon University (Dec 18) | Kathryn Hess, École polytechnique fédérale de Lausanne (Jan 8) | Adam Summers, University of Washington (Jan 15) | Mark Pauly, École polytechnique fédérale de Lausanne (Jan 29)

FUTURE SPEAKERS: Elaine Fuchs, The Rockefeller University (Mar 5) | Olga Sorkine-Hornung, ETH Zurich (Mar 12) | Lieven Vandersypen, TU Delft (Mar 19) | Luca Cardelli, Microsoft Research (Apr 9) | Yukiko Goda, RIKEN Brain Science Institute (Apr 16) | Jürg Fröhlich, ETH Zurich (Apr 23) | Walter Fontana, Harvard University (Apr 30)

SELECTED RECENT PUBLICATIONS

Ajanki, Oskari H, Erdős, László, Krüger, Torben: Universality for general Wigner-type matrices. In: Probability Theory and Related Fields. Springer, 3-4, 2017, 667-727.

Alt, Johannes, Erdős, László, Krüger, Torben: Local inhomogeneous circular law. In: Annals Applied Probability. Institute of Mathematical Statistics, 2018, Preprint.

Barton, Nicholas H, Etheridge, Alison M: Establishment in a new habitat by polygenic adaptation. In: Theoretical Population Biology. Academic Press, 2018, Epub ahead of print.

Budanur, Nazmi B, Short, Kimberly Y, Farazmand, Mohammad, Willis, Ashley P, Cvitanović, Predrag: Relative periodic orbits form the backbone of turbulent pipe flow. In: Journal of Fluid Mechanics.

Cambridge University Press, 2017, 274-301.

Fraisse, Christelle, Picard, Marion A, Vicoso, Beatriz: The deep conservation of the Lepidoptera Z chromosome suggests a non canonical origin of the W. In: Nature Communications. Nature Publishing Group, 1, 2017, Article number: 1486.

Giacobbe, Mirco, Guet, Calin C, Gupta, Ashutosh K, Henzinger, Thomas A, Paixão, Tiago, Petrov, Tatjana P: Model checking the evolution of gene regulatory networks. In: Acta Informatica. Springer, 8, 2017, 765-787.

Kutzer, Megan A., Kurtz, Joachim, Armitage, Sophie A: Genotype and diet affect resistance, survival, and fecundity but not fecundity tolerance. In: Journal of Evolutionary Biology. Wiley-Blackwell, 1, 2018, 159-171.

Lemeshko, Mikhail, Schmidt, Richard: Molecular impurities interacting with a many-particle

environment: From ultracold gases to helium nanodroplets. In: In Cold Chemistry: Molecular Scattering and Reactivity Near Absolute Zero , 11:444-495 (Theoretical and Computational Chemistry Series). The Royal Society of Chemistry, 2017, 444-495.

Napiórkowski, Marcin, Reuvers, Robin, Solovej, Jan P: The Bogoliubov free energy functional II: The dilute Limit. In: Communications in Mathematical Physics. Elsevier, 2017, Epub ahead of print.

Ringbauer, Harald, Kolesnikov, Alexander, Field, David, Barton, Nicholas H: Estimating barriers to gene flow from distorted isolation by distance patterns. In: Genetics. Genetics Society of America, 2018.

A full list of publications from IST Austria can be found at publist.ist.ac.at.