

Foreword



Quantum mechanics is our most fundamental theory of reality. Yet for large physical systems, interesting quantum-mechanical features tend to disappear. Consider Schrödinger's famous thought experiment of a cat that is in a superposition of both dead and alive. It's easy enough to accept that a hydrogen atom can be in a superposition of two states. But Mr. Whiskers? Never!

I study electronic systems that break the trend pointed out by Schrödinger's cat. That is, systems which are large and complicated, yet remain essentially quantum-mechanical in nature. In practice, this means building small devices that combine superconductors, semiconductors, and mechanical motion and operating them at ultra-low temperatures. The grand goal is to find, or build, a system where fragile quantum properties such as superposition and entanglement actually get more resilient as the system grows. Aside from the fascinating physics that emerges as a result, this idea turns out to be deeply connected to information processing, and could enable error-resilient quantum computers.

Because of the close connection between my work and technology, my previous positions have been in joint settings between government, industry, and academia. Before joining IST Austria I was a postdoctoral fellow at the National Institute of Standards and Technology/JILA in Boulder, CO, and afterwards a researcher at Microsoft Quantum, Copenhagen. As I complete my first year at IST, I'm thrilled to be launching the lab and forming ties with the exciting cluster of quantum-related research groups already present at the institute.

Andrew Higginbotham | Assistant Professor, IST Austria



Johannes Kepler University Linz (JKU) and IST Austria thrilled to join ELLIS network

The Institute for Machine Learning and the LIT AI Lab (JKU) as well as IST Austria have been selected as two Austrian research institutions to become an ELLIS (European Laboratory for Learning and Intelligent Systems) location.

ELLIS aims to develop a European network to support and to connect institutes of excellence as well as strengthen and foster groundbreaking basic research in the field of artificial intelligence, machine learning, and deep learning.

Christoph Lampert, coordinator of ELLIS at IST Austria, remarked: "Developments in machine learning will have an impact on all of us, on our whole society. Basic science will be key to understand not only what modern machine learning systems are doing, but also why. We should not leave answering these questions to researchers in America and Asia, but European researchers should take leading roles as well."

IST Austria – a place of growth

With four new professors joining the Institute in 2019, the number of research groups at IST Austria has increased to 53. In the spirit of curiosity-driven basic research, Professors Mario de Bono (neuroscience), Andrew Higginbotham and Scott Waitukaitis (physics) as well as Marco Mondelli (computer science) study a diverse range of interdisciplinary topics including neuronal circuitry, machine learning, complex material science, and quantum computing.

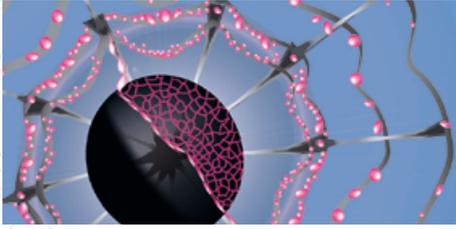
2020 will be another year of growth, with six new professors joining IST Austria in the coming months to conduct excellent research. The first professor to arrive was Kimberly Modic (physics) in January. At IST Austria, she will combine custom-built thermodynamic probes with state-of-the-art sample preparation for the investigation of unconventional superconductors, topological materials, and spin liquids.

ERC 'Consolidator Grant' awarded to Professor Krishnendu Chatterjee

The European Research Council (ERC) has awarded Professor Krishnendu Chatterjee a 'Consolidator Grant' for the improvement of algorithmic tools for probabilistic or stochastic models. Stochastic models are foundational to many scientific disciplines and increasingly to emerging technologies such as artificial intelligence and game theory simulations.

Krish Chatterjee's project—in collaboration with scientists from the University of Vienna and Harvard University—aims to develop algorithmic solutions that will help better analyze the output from stochastic models. This new approach towards reconceptualizing the algorithmic aspects for the 'formal methods' used for stochastic models will inevitably benefit other scientific disciplines as well as emerging technologies such as social cooperation modelling and artificial intelligence.

Research Highlights



Biochemistry meets mechanics: the sensitive nature of cell-cell contact formation in embryo development

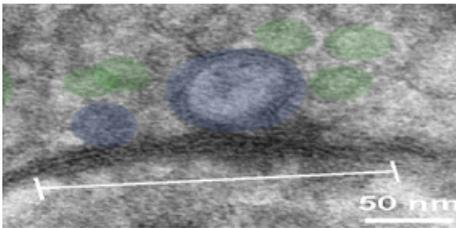
There is increasing evidence that the concerted actions of mechanical and biochemical signals drive key cellular processes. While the biochemical basis of these processes is quite well understood, comparably little is yet known about the mechanical forces involved. In their study published in *Cell*, PhD student Cornelia

Schwayer and colleagues from the group of developmental biologist Carl-Philipp Heisenberg together with collaborators from the University College London, UK, have identified a novel mechanism by which biochemical and mechanical signals cooperate in cell-cell contact formation within the early zebrafish embryo—involving protein phase separation as a key feature of this process.

After the fertilization of a fish egg, the first cell divisions give rise to a mound of cells, which settle on the egg's yolk. These cells will divide further and form different kinds of tissues. To do so, they first need to rearrange and spread out in a way that they end up covering the whole of the yolk's surface. This cell movement is supported by contracting actomyosin structures in the yolk—similar to their well-known counterparts from muscle contraction—that drag the cells along the

egg's surface until a thin layer of embryonic cells engulfs the yolk mass. How these actomyosin filaments dock to the surface epithelial cells to exert the dragging forces, however, has remained unknown. Schwayer and colleagues identified a specific cell-cell junction protein by the name of ZO-1.

ZO-1 responds to and scales with tension generated by the actomyosin cytoskeleton of the yolk cell to which tight junctions are connected: the higher the tension, the more ZO-1 accumulates at the forming junction. In turn, ZO-1 controls actomyosin network tension and flow within the yolk cell. "This positive feedback loop between tight junction and actomyosin network formation points at a still underestimated crosstalk between mechanical and biochemical signals in tight junction formation", Schwayer concludes.



"Flash and freeze" reveals dynamics of nerve connections

Uniting structure and function of synapses is challenging: Function is studied in living tissue, measuring electrical signals at millisecond precision with electrophysiology, while the observation of fine structure at nanometer scale requires tissue to be fixed for electron microscopy. Professor Peter Jonas and his group members, first authors Carolina

Borges-Merjane (postdoc) and Olena Kim (PhD student), have developed a so-called "flash and freeze" method for studying structure and function of synapses in intact neural circuits in mammalian brain slices. The study has been published in *Neuron*.

"Flash and freeze" refers to the flash of light used to stimulate the neurons, followed by immediate freezing of the tissue to fix it in its most native state. The sample is then dropped into a tank of liquid nitrogen and prepared for analysis by electron microscopy.

This set-up allows neuroscientists to stimulate neurons and freeze the tissue immediately afterwards for analysis by electron microscopy, so that changes in anatomy right after stimulation become visible. "It

is a very dynamic way of studying synapses", explains Borges-Merjane, "we can flash and then freeze immediately or wait a few milliseconds or even seconds. By taking several such snapshots, we reveal the time course of structural changes that happen during synaptic transmission."

In a proof-of-principle experiment, the researchers analyzed pools of vesicles at a cortical synapse and found that the structurally defined "docked" pool and the functionally defined "readily releasable pool" of synaptic vesicles are in fact revealed to be very nearly the same, once observed and analyzed using their new integrated method. "This has never been demonstrated directly. Our finding underlines how important it is to extend studies of both structure and function to cortical circuits", Jonas adds.



Geometry meets time: when 2D print-outs fold themselves into complex 3D objects

Ruslan Guseinov, PhD student in the group of Professor Bernd Bickel—in collaboration with researchers from Caltech, USA, and Rey Juan Carlos University, Spain—have successfully demonstrated a novel mechanism of temporal morphing of self-actuated shells. The research

has been published in *Nature Communications*.

In his previous project, Guseinov demonstrated so called "CurveUps": flat sheets that transform themselves into smooth-surfaced, free-form objects. Going one step further with the current project, the aspect of time has come into play. How can you ensure that each part of the structure folds at a defined rate? Hereby, two new aspects had to be considered: a mechanism that encodes both time and geometry, and an algorithm to program this "smart" material for a specific target object.

To further demonstrate the novel mechanism, the Bickel group also demonstrated the new method with designing, printing and assembling a doubly curved shape, a double spiral, and a sheet self-

interweaving shape. With its unique behavior, this mechanism offers sturdy structures, for example a mobile stand carrying twice its weight while remaining practically undeformed. PhD student Guseinov on his new publication: "We developed new concepts for self-morphing metamaterials with rich functionality to replicate highly non-trivial shapes. In my opinion, this is a significant step towards the industrial design of products that autonomously self-assemble on request. I find this exciting and I am very curious to find out how to turn our findings into a viable technology." Further potential applications could be seen in the medical or aerospace realms, as well as in aesthetically curved furniture with sequentially interlocking joints, or the outer shells of aerodynamic drones.

Outreach



Outreach - Outlook 2020

In addition to conducting world-class science at the IST Austria campus, 2020 brings a new year of events and other outreach opportunities to engage people who are interested in science, and to communicate the importance and role of science for society. Here is an overview of the events currently planned in 2020:

The **Science Education Day on March 11** kicks off a range of fantastic outreach activities this year. The event is specially designed for teachers and teachers in training, scientists and all those interested in increasing their expertise on how to effectively teach science.

On **May 8**, the campus opens its doors to the annual public for the nationwide “**Long Night of Research**”

science communication festival held in Austria.

The **Open Campus**, IST Austria’s biggest science festival, will take place on campus on **June 7** from 12:00 to 18:00. It is the annual celebration of the Institute’s inauguration anniversary and includes various science related activities suitable for the whole family.

A summer full of outreach activities

During the summer months, IST Austria hosts a wide range of outreach events and science camps with the aim to engage children in natural sciences. The three main events for eager young scientists are the “Kinderuni”, “Sommercampus” and “Talentesommer”.

On **July 23**, participants of the “**Kinderuni**” get the opportunity to visit the campus and experience a day full of research activities.

During the late summer months, IST Austria’s two science camps for children take place. Starting **August 24 to 28**, kids aged from six to twelve years can participate in the “**Sommercampus**”. The [registration](#) opens on March 3.

This event is followed by the “**Talentesommer**” from **August 31 to September 4**, for kids aged from twelve to sixteen. During both camps, kids get the chance to learn, experiment, and work on their own research projects.

IST Lectures

IST Lectures are public events that take place year round and focus on current developments in science. There are already two upcoming IST Lectures announced for 2020: “Re/Nationalizing Europe? The Austrian case 1995-2015” by **Ruth Wodak on March 26** and “Single-particle cryo-EM: Visualization of biological molecules in their native states” by **Joachim Frank on April 21**. Ruth Wodak is a Professor at Lancaster University, UK and Joachim Frank a Professor at Columbia University, USA.

Missed a previous event at IST Austria? Watch the videos of some of the lectures and events on our [YouTube channel!](#)

For more information about events and outreach activities visit the [website!](#)

SSU spotlight



Annual Austrian High Performance Computing meeting (AHPC)

“Scientific Computing” is one of eight Scientific Service Units (SSU) currently established at IST Austria. It provides High Performance Computing (HPC) resources to scientists on campus.

HPC operates at the limits of computationally feasible problems, and helps to conquer new territory of science. Learning about current limitations is important to remain competitive. The exchange of ideas how to address these issues is key for the further development in science and technology.

To ensure the best possible support to scientists in their computing needs, the scientific computing department operates a HPC cluster, which currently consists of about 150 computing nodes and nine storage servers connected by a high-speed network. This system is available to all scientists at IST Austria, and is used by more than 300 scientists from 35 different research groups per year.

As HPC is a fast moving field, it is of vital importance to keep up to date with the latest developments and to have a national and international exchange of ideas and expertise.

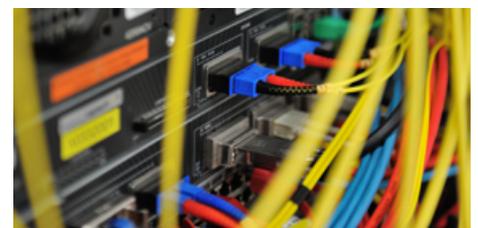
A key event to support this endeavor is the annual Austrian HPC meeting. In the past, the HPC community has already met at other locations in Austria, and this is the first time that it takes place at IST Austria in Klosterneuburg.

The Austrian High-Performance-Computing meeting (AHPC2020) will take place on campus from February 19 to 21, 2020. The

Scientific Computing SSU received 50 abstracts, and expects about 100 participants from Austria and abroad.

The main topics at AHPC2020 will be scientific HPC applications from various fields – this year the emphasis lies on “Cryogenic electron microscopy (cryo-EM)”, optimization in hardware and software, storage technology as well as European and Austrian HPC activities. The Austrian HPC meeting will be an excellent opportunity to present and learn about the latest research results, and to exchange ideas between the users and providers of HPC resources.

For more information about the event visit the [AHPC meeting website](#).



Development and Stem Cells – Regional Meeting 2020

The aim of the 3rd “Development and Stem Cells” regional meeting on February 28, 2020, is to initiate a scientific dialogue, exchange of know-how about new technologies, and open opportunities for collaboration between groups and institutes around Vienna.

The goal is to encourage the establishment of a coherent scientific community in the area, which is why the meeting is free of registration fees. This conference is also specifically aimed at PhD students and postdocs. Everyone is thus encouraged to submit abstracts for poster presentations. Several abstracts will be selected for short talks. There will also be 1 min flash-talks to advertise posters. Apart from talks by PhD students and postdocs, two keynote lectures will be given by Professor Anna Kicheva (IST Austria) and Nicolas Rivron (Institute of Molecular Biotechnology).

For more information about the regional meeting visit the [website](#).



Development and Stem Cells
Regional meeting
February 28, 2020
IST Austria
Joint meeting of the developmental and stem cell biology community in the Vienna area

Keynote speakers:
Anna Kicheva (IST)
Nicolas Rivron (IMBA)

- hear talks by students and postdocs
- attend and present in the poster session
- flash-talks for poster presenters
- meet developmental and stem cell biologists in the Vienna area, find new collaborators
- exchange technology, approaches and ideas

Organizers:
Christo Bunickov, Max Perutz Labs
Edouard Hannezo, IST
Andrea Pasik, IMP
Oleg Simakov, University of Vienna

Registration and abstract submission deadline: February 15, 2020
<https://www.development-stemcells.com/>

Participating groups include:
IST Austria, IMP, IMBA, MFL, University of Vienna, Medical University of Vienna
We are grateful to the participants!



SCIENCE EDUCATION DAY 2020
LERNEN DIGITAL
WIE MACHEN WIR DAS?

11. März 2020
14.00–18.00 Uhr

IST AUSTRIA | Raiffeisen Lecture Hall
Klosterneuburg

SAVE THE DATE!

Details & Registration: www.ist.ac.at/edu20

Science Education Day 2020

On March 11, the Science Education Day themed “Digital Learning“ will again take place on campus. Please be aware that the event will mainly be held in German.

The Science Education Day is the annual event for teachers, scientists and all those interested in communicating science. It is an opportunity to discuss questions about science education and its newest methods.

For more information about the Science Education Day, please visit the [website](#).

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Nir Shavit, MIT (Nov 25) | Subhash Khot, New York University (Nov 29) | Alex Badyaev, University of Arizona (Dec 16) | Erich Bornberg-Bauer, University of Münster (Jan 13)

FUTURE SPEAKERS: Stefan Hell, Max Planck Institute for Biophysical Chemistry (Feb 18) | Karl Ziemelis, Chief Physical Sciences Editor Nature (Feb 24) | Rajeev Alur, University of Pennsylvania (Mar 9) | Helmut Bölskei, ETH Zurich (Mar 16) | Marta Kwiatkowska, Oxford University (Mar 30) | Jean-Daniel Boissonnat, Inria Sophia-Antipolis (Apr 20)

SELECTED RECENT PUBLICATIONS

Laukoter S, Beattie RJ, Pauler F, Amberg N, Nakayama KI, Hippenmeyer S. 2020. Imprinted Cdkn1c genomic locus cell-autonomously promotes cell survival in cerebral cortex development. *Nature Communications*. 11, 195.

Goharshady AK, Mohammadi F. 2020. An efficient algorithm for computing network reliability in small treewidth. *Reliability Engineering and System Safety*. 193, 106665.

Hausel T, Mereb M, Wong M. 2019. Arithmetic and representation theory of wild character varieties. *Journal of the European Mathematical Society*. 21(10), 2995–3052.

Chatterjee B, Peri S, Sa M, Singhal N. 2019. A simple and practical concurrent non-blocking unbounded graph with linearizable reachability queries. *ACM International Conference Proceeding Series*. ICDCN:

Conference on Distributed Computing and Networking 168–177.

Merrill RM, Rastas P, Martin SH, Melo Hurtado MC, Barker S, Davey J, Mcmillan WO, Jiggins CD. 2019. Genetic dissection of assortative mating behavior. *PLoS Biology*. 17(2), e2005902.

Mitosch K, Rieckh G, Bollenbach MT. 2019. Temporal order and precision of complex stress responses in individual bacteria. *Molecular systems biology*. 15(2), e8470.

Zwiewka M, Bielach A, Tamizhselvan P, Madhavan S, Ryad EE, Tan S, Hrtyan M, Dobrev P, Vanková R, Friml J, Tognetti VB. 2019. Root adaptation to O₂-induced oxidative stress by ARF-GEF BEN1- and cytoskeleton-mediated PIN2 trafficking. *Plant and Cell Physiology*. 60(2), 255–273.

Fraisse C, Puixeu Sala G, Vicoso B. 2019. Pleiotropy modulates the efficacy of selection in drosophila

melanogaster. *Molecular biology and evolution*. 36(3), 500–515.

Henderson NT, Le Marchand SJ, Hruska M, Hippenmeyer S, Luo L, Dalva MB. 2019. Ephrin- controls excitatory synapse density through cell-cell competition for EphBs. *eLife*. 8, e41563.

Marhavá P, Hörmayer L, Yoshida S, Marhavý P, Benková E, Friml J. 2019. Re-activation of stem cell pathways for pattern restoration in plant wound healing. *Cell*. 177(4), 957–969.e13.

Cipolloni G, Erdős L. 2019. Fluctuations for differences of linear eigenvalue statistics for sample covariance matrices. *Random Matrices: Theory and Application*.

A full list of publications from IST Austria can be found in the [IST Austria Research Explorer](#).