NEWSLETTER 28th edition | Spring 2019

IST AUSTRIA
Institute of Science and Technology
10 YEARS

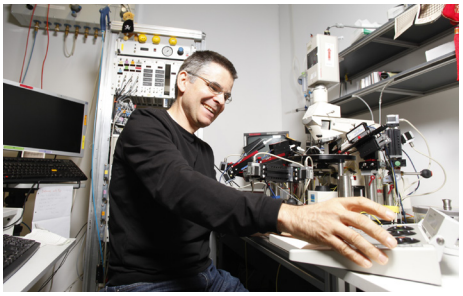
Foreword

Nanomaterials are defined as materials with features as small as one billionth part of a meter. The properties of matter change with size, and when it is scaled down to nanoscale, new phenomena appear. But limitations in the control over the nanostructures of solid state materials are hampering our understanding of structure-property relationships at the most fundamental level. A model system can be envisioned by using well-defined nanocrystals as artificial atoms to build up materials. At IST Austria, I will use colloidal synthetic routes to grow nanocrystals with precise control of size, shape, crystalline phase and composition to investigate their properties and applications as a function of their finely tunable characteristics.

This type of research has an intrinsic interdisciplinary nature. Having a background in physics, I soon realized I needed to expand my understanding of chemistry. During my PhD, I conducted short-term research at different chemistry labs in the University of Chicago or the California Institute of Technology. For my postdoctoral research, I spent three years at the laboratory of inorganic chemistry at ETH Zurich trying to understand the chemical principles behind nanocrystal synthesis and their surface ligation.

I started at IST Austria last September, where I am currently setting up my laboratory. The few months that I have been here have been an incredible experience getting to know how everything works. One can truly see there is a collective and continuous effort to achieve excellence. I can't wait to grow my research group and participate in the scientific productivity of this institution.

Maria Ibáñez | Assistant Professor, IST Austria



Erwin Schrödinger Prize awarded to Neuroscientist Peter Jonas

IST Austria Professor Peter Jonas received the Erwin Schrödinger Prize of the Austrian Academy of Sciences. The annual prize is awarded to scholars who work in Austria and have achieved outstanding scientific results in the subjects represented by the mathematics and natural sciences class of the Austrian Academy of Sciences. The Erwin Schrödinger Prize 2018 went in equal parts to Peter Jonas and Elly Tanaka, a biochemist at the Research Institute of Molecular Pathology (IMP).

Jonas was honored for his outstanding research in neuroscience, in particular for his significant contribution to the understanding of synaptic signal processing at the molecular and cellular level. Among other things, he was able to show the amazing energy efficiency of signal transmission. His research on mechanisms of storage, retrieval and differentiation of memories in the hippocampus could also lead to an understanding of the mechanisms underlying brain diseases.

OECD report praises achievements of IST Austria

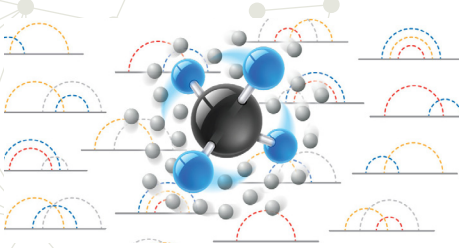
In the nine years since its campus opened, IST Austria established itself as an international center for excellent basic research. This is acknowledged by the OECD in its latest report on Austrian innovation policy. The document presented by Science Minister Heinz Faßmann and Infrastructure Minister Norbert Hofer testifies to the good development of the Austrian research landscape. Particularly highlighted was the "remarkable research record" of IST Austria. The "institutional innovation" IST Austria had met the high expectations placed on it.

The report explicitly identifies IST Austria as one of the strengths of the Austrian research landscape. Particular praise is given to the exceptionally high success rate in obtaining competitive grants from the European Research Council (ERC) and the total number of such grants obtained: with 37 grants in the observation period, IST Austria is responsible for a considerable proportion of the total of 125 grants awarded to Austria.

Computer Scientist Bernd Bickel receives (technical) Oscar

Austria has another Academy Award winner. Having honored actor Christoph Waltz (2010, 2013) and director Michael Haneke (2013), the Oscar Academy of Motion Picture Arts and Sciences has awarded IST Austria Professor Bernd Bickel, a computer scientist from Vorarlberg, with this year's Technical Achievement Award. This prize is granted each year two weeks before the Academy Awards of Merit ("Oscars"). Bernd Bickel will be given the prize on February 9 at the award ceremony in Los Angeles.

Bernd Bickel and his former colleagues Thaboo Beeler, Derek Bradley and Markus Gross will receive the prestigious award for developing a computer-based system which allows translating facial expressions and gestures from human beings to animated characters. The "Medusa" system was used in such films as "Maleficent", "Star Wars" and "Pirates of the Caribbean". From 2010-2014, Bernd Bickel was part of the team at Disney Research in Zurich that developed "Medusa".

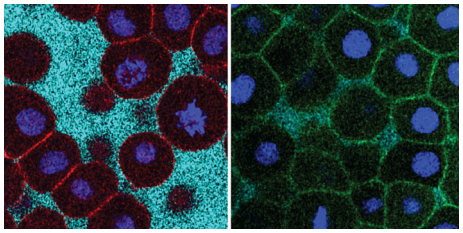


Description of rotating molecules made easy

Feynman diagrams are a powerful tool in condensed matter physics. By turning highly complex equations into sets of simple diagrams, the method has established itself as one of the sharpest tools in a theoretical physicist's toolbox. Giacomo Bighin, a postdoc in Mikhail Lemeshko's group at IST Austria, has now extended the Feynman diagram technique: originally devised for subatomic particles, the simplest objects imaginable, the technique can now work with molecules, far more complex objects. The research, which was published in Physical Review Letters, is expected to drastically simplify the description of molecular rotations in solvents.

"Molecules always rotate, and how they interact with one another depends on their relative orientation. If they hit another molecule with one end, it has a different effect than if they hit it with the other end," explains Mikhail Lemeshko. The orientation of molecules and hence chemical reactions have already been controlled in experiments on molecular gases, but it is quite challenging to do the same in solvents. This is a long-term goal the Lemeshko group is working towards. The step they have just taken is about being better able to describe the rotation of a molecule in a solvent—a prerequisite for eventually controlling reactions in this environment.

Transferring the method, however, was not easy. "Feynman diagrams work for point-like particles such as electrons. Point-like means that they are not affected by rotations: if you rotate an electron, it looks exactly the same as before. Molecules, on the other hand, are more complex and can rotate and change their orientation in space," explains Giacomo Bighin. In order to transfer the method from electrons to molecules, he had to develop a new formalism. Previously, it was not known if it would even work for molecules, and adapting the method took Bighin more than a year. Now the formalism is ready to use in chemical problems.

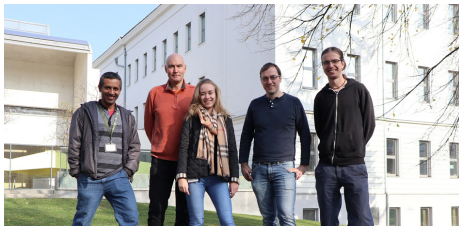


When a fish becomes fluid

Zebrafish are not just surrounded by liquid, but turn liquid - in part - during their development. As the embryo develops from a ball of cells to a fully-formed fish, a region of the embryo switches its phase from viscous to liquid. Such fluidity transition has long been speculated to exist in living matter, but is described for the first time to occur in a living organism in a Nature Cell Biology study carried out by the group of Carl-Philipp Heisenberg at IST Austria, with first author Nicoletta Petridou, and the group of Guillaume Salbreux at The Francis Crick Institute and Edouard Hannezo, also at IST Austria.

Zebrafish are particularly suited for studying animal development as the embryo is transparent and develops outside the mother. At the beginning, a tissue layer called blastoderm spreads over the yolk. The blastoderm changes shape to form a dome, hence this process is known as 'doming'. The researchers investigated the mechanical forces at play during this shape change. By applying pressure to embryonic tissue through a pipette and measuring how fast it deforms, they could infer how viscous the tissue is: tissue that deforms slowly is less fluid than tissue that deforms quickly. Repeating the experiment at several time points and regions in the developing embryo, they found that during doming, the tissue suddenly fluidizes at a very specific time and tissue region.

Why and how does zebrafish tissue become liquid? In "normal" viscous tissue, the cells are in close contact with each other. The scientists found that the fluidity transition happens because cells keep on dividing during development. During division, the cells become round and detach from their neighbors. The more the cells divide, the more connections are lost between them, until they eventually lose so many contacts that the tissue turns liquid. "This is a mechanical and not biochemical change", explains Petridou, "The embryo is programmed to divide, it cannot escape it."



No cooperation without open communication

Indirect reciprocity is a model that explores how humans act when their reputation is at stake. Previous studies have assumed that everyone in the population has all the relevant information and that everyone agrees who is good and bad. In a new model published in PNAS, Christian Hilbe, Laura Schmid, Josef Tkadlec, and Professor Krishnendu Chatterjee at IST Austria, together with Professor Martin Nowak of Harvard University, explore what happens when information is incomplete and people make mistakes.

In game theory, indirect reciprocity is played out using two randomly selected individuals in a population: one donor, one recipient. The donor needs to decide whether or not to help the recipient based on their social norms. The donor's decision may depend on the reputations of the two individuals, and on the social norm the donor employs. Meanwhile, the rest of the population watches: after the donor's decision, they update their opinions of him or her based on their own social norms. Past models have assumed that everyone agrees on the reputations of everyone else, and that everyone witnesses all interactions. These studies have shown that there are eight strategies that lead to stable cooperation in a population.

Exploring how the leading eight strategies fare when faced with incomplete information, the scientists have found that none leads to high levels of cooperation, and many are unstable or do not evolve at all. Even a single difference of opinion in the population could have drastic effects. If the donor thinks the recipient is bad, but the rest of the population thinks the recipient is good, the donor's decision not to give causes his or her reputation to drop, resulting in a ripple effect throughout the population. But the researchers have also gathered numerical evidence that communication among individuals reduces errors and increases cooperation.

ProfTalk

Nick Barton, Evolutionary Biologist

What was your original field of study? I started out doing an undergraduate degree in Cambridge called Natural Sciences, which was quite an unusual degree in that it covered the whole of the sciences. I had gone in intending to study physics but found biology more interesting because it was new, and ended up specializing in genetics.

Why did you become a scientist? I had always been fascinated by science. As a child I tried building computers, tinkered with electronics, and also enjoyed mathematics. So it was natural for me to go into a science degree.

What do you like about basic research? The appeal of basic research for me is the freedom to pursue questions that no-one has solved as yet, pursue them in unexpected directions and then get the surprise and satisfaction of usually unexpected answers.

What is your main area of research? I started out studying hybrid zones, which are narrow regions where distinct populations come together, produce hybrids and yet remain separate and distinct. Initially, I did a lot of field work, but this field research generalized into mathematical modelling of systems which are distributed over space and which involve interactions amongst many genes.

Which scientific result are you particularly proud of? On the more basic research side, I have been very pleased to go from understanding a specific system to studying much broader questions. One of the questions has been to find and understand why so many organisms have sexual reproduction, why they go to the trouble of finding a mate and mixing their genes with their mate, producing a recombinant offspring. This has been a field, where we have made theoretical progress over the years, partly coming from taking techniques from different fields.

On the more practical side, something that I have been involved with recently is a program to control dengue fever. The idea is that you can infect mosquitoes which transmit dengue with a bacterium called Wolbachia, which surprisingly makes them resistant to transmitting the disease. Released in Cairns in Northern Australia, they really seem to have stopped transmission. My contribution has been to see the mathematical models of hybrid zones that I have worked on for a long time apply directly to the spread of Wolbachia infection. So one can use them to optimize the control program, to decide how many mosquitoes you need to release and where to release them most efficiently.

Why did you join IST Austria? I joined IST Austria in 2008, when the whole campus was a building site. I came because I was looking for a job in Europe, and there are not so many places that are good in evolutionary biology. The Vienna region is one of very few real concentrations of the subject.

What is special about IST Austria? IST Austria emphasizes basic research and covers the whole of the sciences. Here we have the opportunity to talk to people in a whole range of different disciplines, which is very stimulating.

Watch the entire ProfTalk interview on video!

SSU spotlight

Establishing cryo-electron microscopy

Cryo-electron microscopy (cryo-EM) is a cutting-edge technique that has led to a series of breakthrough discoveries in biology in the last years. While the development of the method began in the 1970s, recent advances in detector technology and software algorithms have allowed for the determination of biomolecular structures at near-atomic resolution. Today cryo-EM has become an indispensable research tool that enables scientists to observe biological samples in their natural state.

More than one and a half years ago, IST Austria decided to extend the portfolio of its Electron Microscopy Facility by investing in state-of-the-art cryo-EM equipment. First, a survey of the current situation and future development in the field of cryo-EM was conducted. Then, the scientific needs were identified and the technical specifications defined. Last but not least, three machines were ordered and delivered to Lab Building East, close to the labs of IST Austria's structural biologists Carrie Bernecky, Leonid Sazanov, and Florian Schur.

IST Austria's cryo-EM infrastructure includes a high-end 300kV transmission electron microscope for single-particle analysis and cryo-electron tomography, a middle-range 200kV transmission electron microscope for automated sample screening and data acquisition for single-particle analysis, and a dedicated cryo-scanning dual beam/scanning electron microscope for the preparation of frozen, thin lamella samples from biological specimen for high-resolution cryo-electron tomography imaging.

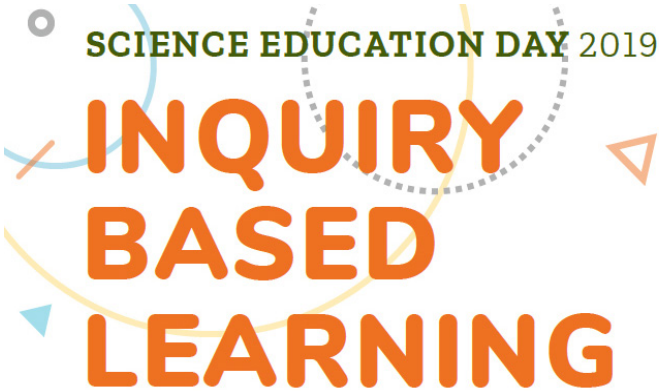
"Like all scientific service units at IST Austria, we are a multi-user facility and optimize our equipment to cover the widest possible range of applications. As soon as all three machines are in full operation, we will be able to do single-particle analysis, which is necessary to study protein and viruses, as well as

cryo-electron tomography, which enables the study of macromolecular complexes in their native cellular environment," states Ludek Lovicar, manager of the Electron Microscopy Facility and responsible for cryo-EM at IST Austria.

The Electron Microscopy Facility is one of eight Scientific Service Units currently established at IST Austria. Its excellently trained staff provides scientists with high-end equipment and cutting-edge technology to address highly sophisticated research questions. It is their task to constantly develop and establish new techniques and methods to ensure that future needs and demands of the scientific community will be met efficiently and with high-quality standards. Further information can be found on the Scientific Service Units website.

IST Science and Society Lecture by Helga Nowotny

Helga Nowotny will speak about "A humble view from inside evolution: towards the Third Paradise?" at the IST Science and Society Lecture on March 6 at 5:00pm. She is Professor emerita of ETH Zurich and Former President of the European Research Council. In her talk she will argue that humans are the only species on Earth with the ability to see evolution from inside. But we as humans should reflect on what we are doing in and with evolution. That is when art comes in. *Il Terzo Paradiso* is an artistic symbol created by Michelangelo Pistoletto, a fusion between nature and artifice. How can a balanced connection be achieved? While we are in the process of creating our future, we are redefining what it means to be human. For information and registration visit the website.



Science Education Day 2019

The Science-Education Day 2019 will be held on March 27. The annual event brings together teachers, scientists and all those interested in communicating science. The 2019 edition will focus on national and international perspectives of inquiry based learning. Leading experts including Petra Van Koppen (University of California–Santa Barbara), Christian Bertsch (University College of Teacher Education Vienna), Suzanne Kapelari (University of Innsbruck) and Haim Harari (former President of Weizmann Institute of Science) will present tools and methods for active learning. The topics of their talks and workshops will range from "Next Generation Science Standard for Science Education" to "Hands-on Evolution–Bridging the Gap between Theory and Practice" and "Science Education for All–A Necessity and a Social Obligation." For information and registration visit the website.

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Michel Milinkovitch, University of Geneva (Nov 5) | Monika Henzinger, University of Vienna (Nov 12) | Molly Przeworski, Columbia University (Nov 19) | Michael Brenner, Harvard University (Nov 26) | Arthur D. Lander, University of California, Irvine (Dec 17) | Michelle Simmons, University of New South Wales (Feb 1)

FUTURE SPEAKERS: Charles Nunn, Duke University (Mar 11) | Paul Steinhardt, Princeton University (Mar 18) | Andrew Mackenzie, Max Planck Institute for Chemical Physics of Solids (Apr 8) | Magdalena Götz, Ludwig Maximilian University of Munich (May 20) | Josh Sanes, Harvard University (May 27)

SELECTED RECENT PUBLICATIONS

Asaoka Y, Morita H, Furumoto H, Heisenberg C-PJ, Furutani-Seiki M. 2019. Studying YAP-mediated 3D morphogenesis using fish embryos and human spheroids. Methods in Molecular Biology. Methods in Molecular Biology vol. 1893,167–181.

Auzinger T, Heidrich W, Bickel B. 2018. Computational design of nanostructural color for additive manufacturing. ACM Transactions on Graphics. 37(4).

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Browning TD, Sofos E. 2018. Counting rational points on quartic del Pezzo surfaces with a rational conic. Mathematische Annalen, 1–40.

Budanur NB, Fleury M. 2019. State space geometry of the chaotic pilot-wave hydrodynamics. Chaos: An Interdisciplinary Journal of Nonlinear Science. 29(1).

Deliu E, Arecco N, Morandell J, Dotter C, Contreras X, Girardot C, Käsper E, Kozlova A, Kishi K, Chiaradia I, Noh K, Novarino G. 2018. Haploinsufficiency of the intellectual disability gene SET disturbs developmental gene expression and cognition. Nature Neuroscience. 21(12), 1717–1727.

Demay G, Gazi P, Maurer U, Tackmann B. 2019. Per-session security: Password-based cryptography revisited. Journal of Computer Security. 27(1).

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Fulek R, Tóth CD. 2018. Crossing minimization in perturbed drawings. Lecture Notes in Computer Science. Graph Drawing and Network Visualization vol. 11282. 229–241.

Reversat A, Sixt MK. 2018. IgM's exit route. Journal of Experimental Medicine. 215(12), 2959–2961.

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Waitukaitis S, Harth K, Van Hecke M. 2018. From bouncing to floating: the Leidenfrost effect with hydrogel spheres. Physical Review Letters. 121(4).

Xu H, Baracskay P, O'Neill J, Csicsvari JL. 2018. Assembly responses of hippocampal C place cells predict learned behavior in goal-directed spatial tasks on the radial eight-arm maze. Neuron. 101(1), 119–132.

A full list of publications from IST Austria can be found in the IST Austria Research Explorer.

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