NEWSLETTER 33rd edition | Summer 2020

IST AUSTRIA
Institute of Science and Technology

Foreword

These are, without doubt, extraordinary times. Accordingly, this is an unusual newsletter. I want to give you a summary of some of the challenges we are faced with at IST Austria, and an update on some of the remarkable ways in which many members of our community have responded. I thank every member of IST Austria for the incredible commitment and efficiency they have all proved, and are continuing to prove, during the shutdown and slow return of the institute, at all times maintaining our focus on keeping interesting science happening.

What seems now a long time ago, all scientists and administrative staff moved into remote mode within a couple of days, setting up their laptops and virtual labs at home, while the activities on campus went into a minimal mode of operations to keep the essential facilities and infrastructure running. Within less than a week, the institute was meeting, teaching, advancing science, and handling all administrative matters remotely. In parallel, the first COVID-19 related ideas and projects popped up, driven – as is befitting for an institute of basic research – bottom-up and committed to excellence. You will find several examples of such projects - from the citizen-science project CoKoNet to the science-education project Pop-Up Science to the "Anti-Viral Ideas" platform Avid - later in this newsletter.

In the meantime, the experimental research groups are back to work on campus, at a reduced but growing scale. Observing all necessary restrictions and precautions, we are carefully shifting the institute from remote to return mode. As always, what keeps us going is our passion for doing and communicating science. In a time like this, this passion is also an obligation. As I have said before, at the end of the day – no matter how long that day may be – it will be science which will beat the virus.

Until this happens, stay safe please.
Thomas A. Henzinger | President, IST Austria

Gašper Tkačik received the highest honor of the Austrian Academy of Sciences (ÖAW)

For his groundbreaking research in recent years, biophysicist Gašper Tkačik received the Ignaz L. Lieben Prize of the Austrian Academy of Sciences (ÖAW), worth 36,000 dollars. Professor Tkačik has already received several awards for his research, including two grants from the Human Frontier Science Program (HFSP) and grants from the Austrian Science Fund FWF.

Gašper Tkačik and his research group investigate biological networks from a distinctly multidisciplinary perspective: using methods and approaches from information theory, statistical physics, biophysics, and biology, he tracks down processes such as chemical reaction chains in cells and neuron connections in the brain. In this way, he hopes to understand, among other things, the transmission of information and the formation of information networks and their biological functions. One goal is to find mathematical theories and models that can describe and predict evolutionary developments of organisms.

ERC grant for soon-to-be IST Austria professor Vadim Kaloshin

The European Research Council (ERC) has awarded soon-to-be IST Austria professor Vadim Kaloshin an "Advanced Grant" for the development of tools to study rigidity and integrability of large classes of dynamical systems.

Vadim Kaloshin is an expert in mathematical physics, deterministic and stochastic dynamics, who will join IST Austria in 2021. In his research, he solved spectral rigidity problems, stating that one can't deform a nearly circular drum without deforming a sound. In a different vein, Vadim Kaloshin is developing a stochastic technique aimed to explain the formation of the Kirkwood Gaps in the asteroid belt in astronomy.

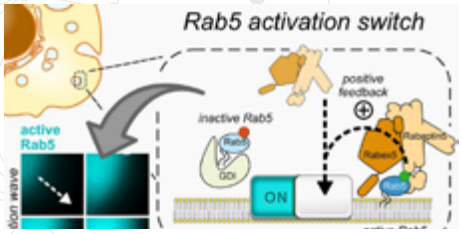
At IST Austria, Professor Vadim Kaloshin and his group will develop tools to study rigidity of drum sounds. If their approach is successful, it will open a path to study rigidity and integrability of many dynamical systems.

Boosting large-scale quantum computing networks

Johannes Fink has been awarded a third Future and Emerging Technologies (FET) grant as part of the EU Horizon 2020 project "SuperQuLAN". The FET program targets groundbreaking research likely to contribute to emerging technologies such as quantum computing. Professor Fink—together with an international consortium of leading scientific experts and industry partners headed by Professor Peter Rabl from TU Wien—will investigate the applicability of using superconducting quantum circuits to produce large-scale quantum computing processors and networks.

Johannes Fink: "Finding new ways to interconnect quantum circuits brings us one step closer to realizing large-scale quantum devices that might unlock unbreakable privacy in communication, quantum cloud computing and unprecedented sensing capabilities, which in turn have the potential to spur on new scientific breakthroughs and advances."

Research Highlights



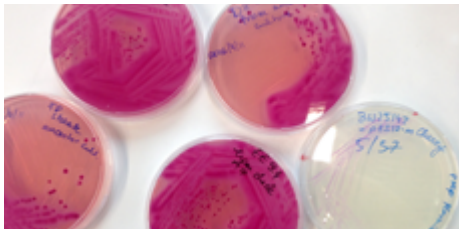
Proteins as molecular switches

A long-standing open question in the field of cell research is that of the self-organization properties of proteins called Rab small GTPases. It was now tackled by Urban Bezeljak, PhD student in the group of Martin Loose, together with theoretical biophysicists from the National University of Singapore, in a study published in the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS).

Rabs control precise funneling of different components inside our cells. The researchers dissected the details of this process by rebuilding it in a test tube, allowing them to directly observe the dynamics of fluorescently labeled proteins under a microscope. Bezeljak explains: "We found out that Rabs function like molecular switches, which can simultaneously switch on thanks to a positive feedback in their activation. This unique feature helps Rabs to orchestrate trafficking of membranes that encapsulate cellular cargo."

The study provides new insights into small GTPase networks that organize our cells in space and time and introduces a unique reconstitution approach, which can be used to study similar regulatory circuits. This understanding is especially important as these biochemical networks are commonly misregulated in cancer, neurodegenerative diseases and infection.

Urban Bezeljak, before joining IST Austria in 2015, obtained his BSc and MSc in biochemistry at the University of Ljubljana, Slovenia. There, he entered the field of synthetic biology and worked on directed protein assembly and designed genetic networks. Urban was able to combine his interests in Martin Loose's lab, where he is finishing his PhD on bottom-up examination of Rab GTPase regulation. In 2018, he received a Tuma Scholarship for exceptional Slovenian graduate students in Austria.



Copy/paste and delete – or how to thrive without gene regulation

Turning genes on and off as needed allows an organism to adapt to changes in the environment—provided the organism has a specific regulatory design in place. PhD students Isabella Tomanek and Rok Grah from the groups of Calin Guet and Gašper Tkačik, and Jonathan Bollback from the University of Liverpool, UK, have shown that under rare or rapidly changing conditions, the fitness of a population of bacteria can increase simply by producing a higher number of copies of one and the same gene. The results are highly relevant in resistance to antibiotics treatment. The study was published in *Nature Ecology & Evolution*.

Uniting their work in this study, the three research groups have demonstrated for the first time that gene copying serves as a strategy to tune the level of gene expression when gene regulation is required but no other genetic regulatory mechanism is in place. Rok Grah says: "Most notably, the copy/paste and delete strategy comes into effect on ecological timescales, i.e. before slower evolutionary solutions like gene regulation on the level of single cells can evolve by adaptation through point mutations. And, as we could show in our model, since any genomic region can basically be amplified, the described mechanism cannot only act on any bacterial gene but it is also applicable, in principle, to any other organism."

The broad applicability of the genetic mechanism described in this study has potential implications for an equally diverse number of biological phenomena. For instance, it may lead to failure of antibiotics because, due to a difference in copy numbers, bacteria from one and the same patient show different levels of antibiotic resistance. This phenomenon called heteroresistance makes it hard for physicians to estimate just how much antibiotic is needed to successfully fight a bacterial infection.

The beginning defines the end

IST Austria postdoc Alexios Michailidis and Professor Maksym Serbyn, together with collaborators from the University of Geneva and the University of Leeds, have successfully linked classical and quantum physics to find the "least chaotic" initial configurations. The study published in the journal *Physical Review X* provides a method for finding configurations most resilient to chaos and gives specific examples that could be tested in future experiments.

Chaos limits our ability to predict the future behavior of classical systems even when the theoretical model is well known. Quantum systems show behavior that is similar in many aspects. However, not much is known about the relevance of classical chaos to interacting quantum systems.

The initial conditions can strongly influence the behavior of a classical system. Just imagine the two situations in a Viennese ball: suppose when the music begins, all partners are standing next to each other, or they are scattered across the dance hall. In the first case, one shall see the beautiful dance pattern, while in the second case, one most likely will observe true chaos. Deriving from such sensitivity of classical systems to initial conditions, scientists managed to give direction which initial states should be constructed to obtain the slowest relaxing behavior in quantum systems. Some of these initial patterns are realizable in the so-called chains of Rydberg atoms, where they lead to a long-lived oscillation.

Maksym Serbyn about the recent findings: "What I like most about this project is that it brings together quantum many-body and classical physics. We have generated experimental predictions that will hopefully be tested very soon." Postdoc Alexios Michailidis adds: "The connection between the many-body quantum dynamics and the phase space structure of the approximate classical system could provide an avenue for generalizing few-body chaos to many-body quantum systems."

Covid-19

IST Austria's COVID-19 Activities

Since March, IST Austria has been developing and sharing various activities to provide more scientific content during these days mostly spent at home. Two notable projects are Pop-up Science and the citizen science project CoKoNet. Recently an internal project, called AVID, was devised as well.

Research instead of boring!

Pop-Up Science was IST Austria's response to the schools closing in Austria as COVID-19 precautions, which posed a challenge for many parents. With this format, the Institute offers online activities to satisfy the curiosity of young researchers. True to the motto "Research instead of boring!" children, ages seven to twelve, get the opportunity to experience fun and educational content. Every week is themed around a scientific topic, which influences the worksheets, experiments, and the scientist who participates in the "Ask the scientist" video. In this way, children playfully learn about research and the everyday work of scientists. More information can be found on the Pop-up Science website!

CoKoNet

CoKoNet is a citizen science project to generate a "collective diary" about how our social behavior is changing in response to the Corona crisis. Throughout this project, data will be collected in an anonymous, web-based survey. It aims at collecting data of how our social interactions change throughout the different phases of the epidemic, compared to our habits before the crisis. Participants are hence asked to fill in information about their social interactions (no detailed data, no health data!) before and at different time points throughout the epidemic.

The survey is being conducted by IST Austria, and collected data will be analyzed as part of the PhD program. Regular survey participants will receive a personal diary in the form of graphs and charts. The aggregated data will be used by the Institute within its Science Communication & Education program in school workshops around the topic of big data analysis, in public lectures and will be shared with the interested public through innovative formats of science communication and education.

Everyone over the age of 14 years can take part in CoKoNet – there is no upper age limit! You can participate and find out more on the infographic or the CoKoNet website.

AVID

AVID (Anti Viral IDeas) is an internal IST platform that provides space and resources to work on new solutions addressing the COVID-19 crisis. Everybody at IST can suggest challenges, post ideas, and register as teammates. Some of the current projects include CoKoNet, improving the design of the open-source ventilator developed by MIT, epidemic modelling for better decision making, and many more. The platform is managed by IST Austria's technology transfer program. Details about the projects can be found on the TWIST website.

SSU spotlight

IST Austria Emergency Ventilator

At the beginning of the spreading of the Corona pandemic, it wasn't fully clear in Austria whether the available ventilators in the hospital will be sufficient for the increasing need of these pieces of equipment. Todor Asenov and his team at the IST Machine-Shop took the initiative to produce a low-cost ventilator similar to the ventilators being developed by MIT E-Vent team. The first prototype of the ventilator was running within 4 days of the project beginning.

This IST-Emergency Ventilator is based upon the idea of pressing an ambu bag, which can be removed and operated manually in case the respirator fails. There are two operation modes: controlled-volume and controlled-pressure respiration. The first mode provides a controlled volume of air to the patient in a set amount of time, while the second maintains a set airway pressure for a given inspiratory time. The design was evaluated by several doctors and was deemed useful in emergencies. In comparison to many similar open-source projects that were developed during the crisis, this ventilator offers an agile operation in which many parameters can be adjusted to suit the situation of the patient.

Proposals have been made from the Technology Transfer Office to the Red Cross to implement this device in areas where proper ventilators are missing. As the normal process for certification takes usually several years, more suitable ways to put the ventilator in operation were necessary. One option was to issue an emergency certification, which can be granted for such devices in Austria in emergency cases, or to make the project available for the public while providing all the technical data that is needed for potential developers to manufacture the ventilator in countries where it is urgently needed. As the spread of the virus in Austria appears to be under control, the second option was taken and the project has been made public on the IST Git Repository.

The Miba Machine Shop is one of eight Scientific Service Units (SSU) currently established at IST Austria. Its team provides expertise in the development and production of mechanical and electronic equipment for specialized experiments as well as on-going technical support. Additionally, they take care of the maintenance, upkeep and emergency repair of scientific instruments and devices.

For more information, visit the MIBA Machine Shop website.

Details about the emergency ventilator can be accessed on the project webpage.

More information on all COVID-19 projects from IST Austria can be found on the AVID website.

IST Austria Events go online!

As many events will not be able to take place on campus the Events Team has been searching for alternatives on how to bring events to the online world. One of those solutions was the option to offer events as webinars. The Institute Colloquium as well as IST Lectures have mostly been switched to online streams. On April 21, the first webinar took place and had Nobel Laureate and Columbia University Professor Joachim Frank talked about 'Single-particle cryo-EM: Visualization of biological molecules in their native states'. On May 13, Florian Schur gave a webinar titled: "Viren, zieht euch warm an! Wie uns „coole" Cryo-Elektronenmikroskopie hilft, die Schwachstelle von Viren zu finden."

For more information about IST events and how they will take place visit the event website.

IST Austria Annual Report 2019

The latest edition of the Annual Report is now available! The report covers research, event, and collaboration highlights as well as the Institute statistics of the anniversary year 2019.

The report is free to download on the IST website.

AHPC 2020 Recap

This year, from February 19-20, 2020, the annual Austrian High-Performance Computing (AHPC) meeting on supercomputing took place IST Austria in Klosterneuburg. 120 national and international experts met to exchange views on aspects of the application in research and the operation of supercomputers.

We would like to thank Europa Science on behalf of all sponsors. The publishing company produces high-quality websites and magazines that target the science and technology sector.

COLLOQUIUM SPEAKERS

PAST SPEAKERS: Alex Badyaev, University of Arizona (Dec 16) | Erich Bornberg-Bauer, University of Münster (Jan 13) | Stefan Hell, Max Planck Institute for Biophysical Chemistry (Feb 21) | Andrea Liu, University of Pennsylvania (May 4)

FUTURE SPEAKERS: Markus Arndt, University of Vienna (Jun 8) | Rich Sutton, University of Alberta and Deepmind (Jul 13) | Anna-Liisa Laine, University of Zurich (Sep 7) | Andrea Cavalleri, Max Planck Institute for the Structure and Dynamics of Matter (Oct 5) | Cristina Marchetti, University of California, Santa Barbara (Oct 12)

SELECTED RECENT PUBLICATIONS

Arbel-Raviv M, Brown TA, Morrison A. 2020. Getting to the root of concurrent binary search tree performance. Proceedings of the 2018 USENIX Annual Technical Conference, USENIX ATC 2018. USENIX: Annual Technical Conference 295–306.

Scarselli D. 2020. New approaches to reduce friction in turbulent pipe flow, IST Austria, 174p.

Kolchinsky A, Corominas-Murtra B. 2020. Decomposing information into copying versus transformation. Journal of the Royal Society Interface. 17(162), 20190623.

Cadavid D, Ortega S, Illera S, Liu Y, Ibáñez M, Shavel A, Zhang Y, Li M, López AM, Noriega G, Durá OJ, López De La Torre MA, Prades JD, Cabot A. 2020. Influence of the ligand stripping on the transport properties of nanoparticle-based PbSe nanomaterials. ACS Applied Energy Materials.

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.

Schlögl A, Kiss J, Elefante S eds. 2020. Austrian High-Performance-Computing meeting (AH), Klosterneuburg, Austria: IST Austria,p.

Bhandari P. 2020. Localization and functional role of Ca.3 in the medial habenula to interpeduncular nucleus pathway, IST Austria, 79p.

Michailidis A, Turner CJ, Papi Z, Abanin DA, Serbyn M. 2020. Slow quantum thermalization and many-body revivals from mixed phase space. Physical Review X. 10(1), 011055.

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Gotfryd D, Paerschke E, Chaloupka J, Oles AM, Wohlfeld K. 2020. How spin-orbital entanglement depends on the spin-orbit coupling in a Mott insulator. Physical Review Research. 2(1), 013353.

Moturu TR, Sinha S, Salava H, Thula S, Nodzyski T, Vaeková RS, Friml J, Simon S. 2020. Molecular evolution and diversification of proteins involved in miRNA maturation pathway. Plants. 9(3), 299.

Zhang X, Adamowski M, Marhavá P, Tan S, Zhang Y, Rodriguez Solovey L, Zwiewka M, Pukysová V, Sánchez AS, Raxwal VK, Hardtke CS, Nodzynski T, Friml J. 2020. Arabidopsis flippases cooperate with ARF GTPase xxchange factors to regulate the trafficking and polarity of PIN auxin transporters. The Plant Cell., tpc.00869.2019.

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

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