

## Foreword



Partial differential equations are a fundamental tool in the description of many phenomena in the sciences, ranging from the mechanics of fluids and solids to questions of population dynamics or pattern formation in biology. My main research interest is the mathematical and numerical analysis of partial differential equations (PDEs) originating from applications in the sciences. A particular focus of mine is on the analysis of modeling errors associated with different PDE models.

My scientific career started at the University of Erlangen-Nürnberg, where in 2013 I received my PhD in mathematics for the analysis of the qualitative behavior of the thin-film equation. After my first postdoctoral position at the University of Zurich, where I came in contact with the analysis of modeling errors, I joined the Max Planck Institute for Mathematics in the Sciences in Leipzig for my second postdoc in 2014.

On my first visit to Klosterneuburg in 2016, I was amazed not only by the exceptional scientific level IST Austria had reached in the short time since its foundation, but also by the openness of its researchers towards interactions with other scientific fields. I have been on campus since January 2017, establishing my own research group. It is a particular pleasure for me to experience the buildup of such a top-level research institute first-hand and I am looking forward to continuing my research in this inspiring scientific environment.

Julian Fischer | Assistant Professor, IST Austria



### Largest grant so far for IST Austria goes to ISTplus postdoc program

Following a competitive, EU-wide application process, IST Austria has succeeded in obtaining funds for an interdisciplinary, international, and intersectoral postdoc program. Funded through the Marie Skłodowska-Curie COFUND scheme, ISTplus will support postdocs at the interface between science and other sectors, such as industry and policy. With a total award amount of almost 4.6 million euros, this is the single largest grant obtained so far by IST Austria.

ISTplus replaces the previous postdoc funding scheme at IST Austria, ISTfellow, which has supported 40 postdocs over the past five years. Through the ISTplus program, which was launched in July 2017, IST Austria will offer 60 two-year fellowships for postdocs with competitive salaries and additional funds for research and travel. Applications are welcomed from all scientific fields currently represented at IST Austria: biology, neuroscience, mathematics, physics, and computer science.



### IST Austria celebrates 15 new PhD graduates

On June 13, IST Austria honored its newest PhD graduates for their work and contributions. The graduating class, which comprises 15 students, is the largest IST Austria has had so far, and the first to reach double-digits.

The evening opened with a musical performance. IST Austria President Tom Henzinger then extended his welcome to the crowd in the Raiffeisen Lecture Hall, recognizing the importance of the day and the diversity of the class, in research area, in nationality, and in career path. In his keynote speech, Harvard Professor Martin Nowak described how the graduating class had exceeded all expectations. The graduates were then introduced by their supervisors, and the audience cheered as, one by one, they crossed the stage to receive their diplomas. The program ended on a musical note, with the IST Austria choir performing a selection of pieces. As they finished, everyone trailed out into the foyer to enjoy a champagne reception.



### Five DOC stipends for PhD students at IST Austria

Five PhD students at IST Austria have been awarded DOC stipends by the Austrian Academy of Sciences (ÖAW). The stipend, worth 38.500 euros annually, will fund their PhD research for a duration of three years. All the awardees—Andi Harley Hansen, Stephanie Kainrath, Hana Semeradova, Julia Steiner, and Stephanie Wachner—work in the life sciences, with research topics ranging from optogenetics to the movement of immune cells.

Training the next generation of world-class scientists is one of the core missions of IST Austria, and the Institute values highly the positive effects that funding schemes such as the DOC stipends have on promising early-career researchers. Planning a multi-year research project and presenting it in a project proposal are crucial skills, essential for a scientist's success. Funding programs like the DOC stipends allow PhD students to have their research plan evaluated in their field in an international review process by experts.



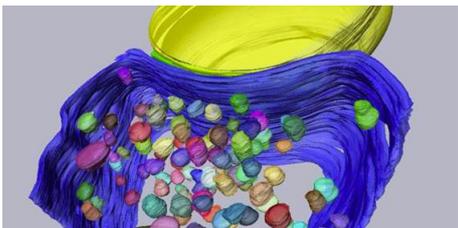
## Making waves

As the equations modeling water surface waves are so difficult to solve in their original form, researchers typically assume that the waves are not “too” big. This simplifies the problem a great deal, but not enough to make it tractable for computer graphics. In the past, this was addressed by making further simplifying assumptions and then using numerical methods to solve the equations. In this approach,

the water waves are represented by a grid of points at different heights above the water surface, and motion is simulated by repeatedly updating the heights of the points based on the heights of their neighbors. However, the visual quality of the simulation depends on how fine the grid is, and it is impossible to quickly produce an image of the waves in the far-off future, as these time-steps must be computed one after another. An initial leap was made in 2007, when a team of researchers departed from the idea of a wave stored on a grid, instead modeling the crest of each wave as a chain of points, and allowing those points to move along the surface as real waves would.

IST Austria Professor Chris Wojtan and former postdoc Stefan Jeschke have applied ideas from

theoretical physics to develop a new type of representation of the waves as packets. Each wave packet contains a collection of similar wavelengths, and larger wave formations are created by adding individual packets together. Breaking up the waves in this way is not new to physics, but it is new to computer graphics, and in this way, the team has developed a simulation that is more versatile and physically plausible than previous methods. As their method is largely independent of time-steps and does not rely on a computational grid, the user can look very far into the future of the simulation, and examine the waves arbitrarily closely. Effects such as reflection, dispersion, refraction, diffraction, and dissipation can be included with minimal extra work, further increasing the quality and believability of the simulation.



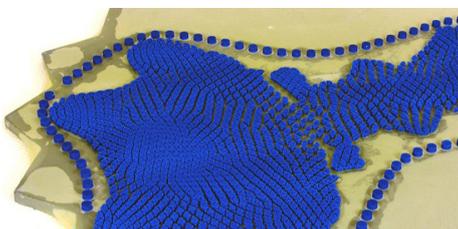
## A docking site per calcium channel cluster

Information in the brain is passed from one neuron to the next at a structure called a synapse. At a chemical synapse, signal transmission requires an elaborate sequence of events. It starts when an electrical signal, the action potential, reaches the synaptic terminal of the presynaptic neuron. This causes the voltage-gated calcium channel to open.

Calcium ions stream rapidly into the presynaptic terminal and the calcium concentration in the presynaptic terminal rises. This allows synaptic vesicles filled with neurotransmitter to fuse with the plasma membrane and release the neurotransmitters into the synaptic cleft. Speed is essential in information transmission. Before the action potential even arrives at the presynaptic terminal, vesicles containing neurotransmitter line up in a fusion-ready state at docking sites in the presynaptic terminal. When the action potential reaches the presynaptic terminal, the vesicles can rapidly fuse and release the neurotransmitter. Functionally, docking sites limit the number of vesicles that can be released at each action potential; this determines the strength of the synapse. Until now, a clear link between the functional aspect of docking sites and

their morphological aspect as sites where vesicles dock could not be established in the mammalian brain.

A PNAS study co-led by IST Austria Professor Ryuchi Shigemoto and Université Paris Descartes Professor Alain Marty establishes the first clear link between the morphology and function of docking sites. Shigemoto and colleagues used a high-resolution electron microscopy technique to look closely at the presynaptic terminal of a particular synapse in the mouse. They found that the number of functional docking sites matches the number of clusters of voltage-gated calcium channels in the presynaptic terminal. In addition, the number of docking sites and the number of calcium clusters change in parallel with brain age and synaptic size.



## Ahead of the curve

3D printers have been around since the 1980s, but we are still far from maximizing their potential. One active area of research and development is “self-actuating” objects: flat materials that transform themselves through material forces into the desired 3D object. Previously, however, the range of objects was limited to those with sharp edges and little, if any, curvature, and the transformation

methods were based primarily on folding or processes that could not be controlled very precisely.

Now, for the first time, a group of current and former IST Austria computer scientists have made it possible to create self-actuating, smooth, free-form objects. In so doing, they developed both an ingenious material design and a new method of self-transformation—they call the fruits of their innovation “CurveUps”. The goal of their project was ambitious. First, it is very challenging to obtain a final 3D object that is mechanically stable. Moreover, they had to develop a controllable mechanism to accomplish this. CurveUps are made up of tiny tiles sandwiched between pre-stretched latex layers. During the transformation, the tension in the latex pulls the tiles together joining them into a continuous shell.

But the innovative design and transformation method were only part of the team’s contribution. With these ideas in hand, Ruslan Guseinov, Eder Miguel, and Bernd Bickel focused on developing tools to create the 2D templates for printing. In particular, their program takes a user-supplied 3D form, and automatically generates a 2D tile layout, including the orientation, location and shape of each tile and connecting pins. However, as even small models will have hundreds or thousands of individual tiles, this represents an optimization problem of tremendous proportions—*infeasible*, on any personal computer. To get around this, the group implemented a two-step optimization procedure, which first gives an approximate solution, then performs local refinements before producing a final template.

## Preview: Neuroscience conferences at IST Austria

Three neuroscience conferences will be held at IST Austria in September. The “Psychiatric Illnesses—From Freud to their biological mechanisms” symposium on September 5 will bring together scientists from diverse fields of neuroscience and psychiatric illness research to give an overview of the current knowledge of the causes of psychiatric illnesses. The European conference on Molecular and Cellular Mechanisms of Neural Circuit Assembly (AXON2017) on September 11-13 will provide a platform for a better understanding of the holistic principles of neural circuit assembly during brain development. The 15th Meeting of the Austrian Neuroscience Association on September 24-26 will serve as a platform for information exchange among Austrian neuroscientists. For more information visit our [website](#).



## Review: Vienna Children’s University at IST Austria

Since its opening in 2009, IST Austria has engaged in a variety of science communication and outreach activities. Now, for the first time, IST Austria has taken part in the Vienna Children’s University, offering a half-day excursion filled with activities and presentations. With about 150 children from Tulln and Vienna in attendance, the event was fully booked.

In a lecture, the young researchers learned how diversity in the animal world develops and about the tricks ants use to survive even the most challenging environmental conditions. In the workshop that followed, students built on what they had learned in the lecture to breed diversity and test the advantages and disadvantages of their dragons in an interactive game. Read more on our [website](#).

## COLLOQUIUM SPEAKERS

**PAST SPEAKERS (May - June):** L. Mahadevan, Harvard University (May 8) | Konrad Lehnert, University of Colorado Boulder (May 15) | Dianne Newman, California Institute of Technology (May 22) | Irit Dinur, Weizmann Institute of Technology (June 19)

**FUTURE SPEAKERS (Oct - Dec):** Christine Jacobs-Wagner, Yale University (Oct 9) | Vinod Vaikuntanathan, Massachusetts Institute of Technology (Oct 16) | Tobias Walther, Harvard University (Oct 23) | Kenneth Birnbaum, New York University (Nov 13) | David Schneider, Stanford University (Nov 29) | Marcos Gonzalez-Gaitan, University of Geneva (Nov 27) | Jean-Michel Raimond, Kastler Brossel Laboratory (Dec 4) | Daniela Grimm, Aarhus University (Dec 11) | Cosma Shalizi, Carnegie Mellon University (Dec 18)

## SELECTED RECENT PUBLICATIONS

Avni, Guy, Guha, Shibashis, Kupferman, Orna: An abstraction-refinement methodology for reasoning about network games. In: IJCAI: International Joint Conference on Artificial Intelligence. AAAI Press, 2017.

Beattie, Robert, Postiglione, Maria Pia, Burnett Laura E, Laukoter, Susanne, Streicher, Carmen, Pauler, Florian M, Xiao, Guanxi, Klezovitch Olga, Vasioukhin Valeri, Ghashghaei, Troy H: Mosaic Analysis with Double Markers Reveals Distinct Sequential Functions of Lgl1 in Neural Stem Cells. In: *Neuron*. Elsevier, 3, 2017, 517-533.

Hansen, Andi H, Duellberg, Christian, Mieck, Christine, Loose, Martin, Hippenmeyer, Simon: Cell polarity in cerebellar cortex development - cellular architecture shaped by biochemical networks. In: *Frontiers in Cellular Neuroscience*. Frontiers Research Foundation,

2017, Article number: 176.

Huylmans, Ann Kathrin, Macon, Ariana, Vicoso, Beatriz: Global dosage compensation is ubiquitous in Lepidoptera, but counteracted by the masculinization of the Z chromosome. In: *Molecular Biology and Evolution*. OUP, 2017.

Lagator, Mato, Paixão, Tiago, Barton, Nicholas H, Bollback, Jonathan P, Guet, Calin: On the mechanistic nature of epistasis in a canonical cis-regulatory element. In: *eLife Sciences*. eLife Sciences Publications, 2017, Article number: e25192.

Maas, Jan, Rumpf, Martin, Simon, Stefan: Transport based image morphing with intensity modulation. In: *SSVM: Scale Space and Variational Methods in Computer Vision (LNCS)*. Springer, 2017, 563-577.

Sachdeva, Himani, Barton, Nicholas H: Divergence and evolution of assortative mating in a polygenic trait model of speciation with gene flow. In: *Evolution*;

*International Journal of Organic Evolution*. Wiley-Blackwell, 2017.

Midya, Bikashkali, Konotop, Vladimir V: Waveguides with Absorbing Boundaries: Nonlinearity Controlled by an Exceptional Point and Solitons. In: *APS Physics, Physical Review Letters*. American Physiological Society, 3, 2017.

Ötvös, Krisztina, Benková, Eva: Spatiotemporal mechanisms of root branching. In: *Current opinion in genetics development*. Elsevier, 2017, 82-89.

von Wangenheim, Daniel, Hauschild, Robert, Fendrych, Matyas, Barone, Vanessa, Benková, Eva, Friml, Jiri: Live tracking of moving samples in confocal microscopy for vertically grown roots. In: *eLife*. eLife Sciences Publications, 2017, e26792.

A full list of publications from IST Austria can be found at [publist.ist.ac.at](http://publist.ist.ac.at).