TRA

Transdisciplinary Research Area

MATHEMATICS, MODELLING AND SIMULATION OF COMPLEX SYSTEMS

UNIVERSITÄT BONN

"Identified application fields developed well, in particular Economics, Geoscience, Life Sciences & Medicine and there are potentially more to come. **TRA MODELLING** aims to expand existing scientific networks and foster upcoming consortia."

In a nutshell

The increasing wealth of data from generations of scientist working in individual disciplines lead to one of the biggest challenges of our time: describing the interaction of numerous individual factors in complex systems with accurate models, predicting complex systems in simulations and, ultimately, yielding a real understanding of how those complex systems actually work. TRA Mathematics, Modelling and Simulation of Complex Systems (Modelling) was launched in 2020 to meet this challenge and bridge the boundaries between disciplines. Ever since our research profile deliberately addresses a broad, open spectrum of inter-/transdisciplinary topics that are understood as "application fields" of the core disciplines of Applied Mathematics and Computer Science. Over the past years, this open concept has proven to be viable. Identified application fields developed well, in particular Economics, Geoscience, Life Sciences & Medicine and there are potentially more to come.

Expanding Existing Scientific Networks

TRA Modelling aims to expand existing scientific networks and foster upcoming consortia in several ways. In line with the Excellence Strategy, 'We invest in people' was implemented in coordination with the Cluster of Excellence Hausdorff Center for Mathematics (HCM) and two faculties when the appointments of the Hertz Chair and the Argelander Professorship were made by TRA Modelling. TRA Modelling, together with TRA Life and Health, supported the establishment of the Interdisciplinary Research Unit Mathematics and Life Sciences (IRU MLS) at the interface of HCM and Cluster of Excellence "Immunosensation[2]" e.g. by jointly organizing a related symposium (2021) and international conference (2023). Geosciences in the ABC/J region benefited from TRA Modelling through seed funding for the successful proposal on the DFG research unit "AlgoForGe" and the Collaborative Research Award 2022, jointly organized with CRC "DETECT". Since 2023 we cooperate with the Center for Earth System Observation and Computational Analysis (CESOC), the European Centre of Medium-range-wheather forecasts (ECMWF) and others in organizing the international workshop Machine Learning for the Earth System Modelling in Bonn. Research involving AI, Robotics and Engineering are reinforced by TRA Modelling in the ongoing activities with the Lamarr Institute for Machine Learning and Artificial Intelligence.

TRA
MODELLING
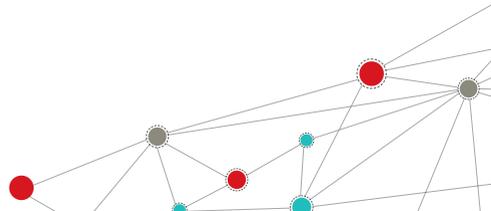
The Opportunity for more Intensive Cooperation

TRA Modelling brings together an increasingly diverse scientific community. Today, 35% of our members are based outside of the Faculty of Mathematics and Natural Sciences, which is already home to a broad spectrum of departments. This versatility offers the opportunity for more intensive cooperation in topics that overlap with the other TRAs, in particular Life and Health, Sustainable Futures and Matter.

TRA spokespersons

TRA Modelling is represented by the spokespersons Prof. Dr. Alexander Effland (Applied Mathematics) and Prof. Dr. Jürgen Gall (Computer Science), who took over this mission from Prof. Dr. Anton Bovier and Prof. Dr. Heiko Röglin in February 2023.

Why am I a spokesperson in the TRA?

Prof. Dr. Alexander Effland
"The main motivation for becoming TRA spokesperson was to further advance existing collaborations between Mathematics/Computer Science and Life Sciences. This way, TRA Modelling will help to initiate new projects with a medical context, that lead to improved modelling and understanding of diseases and ultimately even to better forecast and cure."

Alexander Effland and his research group focus on developing novel mathematical methods for various applications in the Life Sciences including image processing and cardiac modelling with numerous collaboration partners at the University Hospital Bonn.

@ effland@iam.uni-bonn.de

Why am I a spokesperson in the TRA?

Prof. Dr. Jürgen Gall
"Being spokesperson of TRA Modelling is exciting since the TRA is a matchmaker and enabler. The scientific problems become more and more complex and they often cannot be solved anymore without the expertise and models from other disciplines. TRA Modelling connects experts in Modelling and AI with researchers from other disciplines. This not only enables solving problems with better and stronger models, but also investigating completely new ideas to tackle unsolved problems."

Jürgen Gall and his research group develop AI models for understanding and forecasting complex behavior. His group collaborates with researchers from diverse disciplines to solve challenging problems in Agriculture, Earth Science, and Neuroscience.

@ gall@iai.uni-bonn.de

TRA
MODELLING

TRA manager

Dr. Daniel Minge

The TRA management team has several important functions. It serves as an interface between scientists, Rectorate and administration. The TRA managers act as a „transmission belt" to implement the strategic goals of the Rectorate, interconnect the TRAs, and administer all TRA functions in close cooperation with the spokespersons and the TRA's governing bodies. They take a major role in developing and coordinating TRA activities as well as reporting and presenting the TRAs to different target groups. As a key area of work, the TRA managers provide administrative and strategic advice to (future) TRA projects, and foster inter- and transdisciplinary networking of scientists from all career levels. Furthermore, TRA managers were closely involved in the recruitment of the high-profile professorships.

@ daniel.minge@uni-bonn.de

@ tra1@uni-bonn.de

📞 +49 228 73 54462

At the intersection of algorithms, optimization, and game theory

Hertz Chair for
**Algorithms and Optimization**

Prof. Dr.
László Végh

Appointed by TRA Modelling in August 2024, László Végh is also part of the Hausdorff Center for Mathematics, the Institute for Discrete Mathematics, as well as the Department of Economics. His goal in this position is to strengthen the research and teaching links between different departments, and to establish a new research group focusing on algorithmic and optimization problems that may arise in a variety of applications such as resource allocation, logistics, market design, or machine learning.

@ **lvegh@uni-bonn.de**

László Végh is working at the intersection of algorithms, optimization, and game theory. He investigates algorithmic and structural aspects of linear, convex and non-convex optimization problems. He is particularly interested in network optimization questions such as network design and routing, as well as equilibrium computation problems. His research group combines methods from discrete and continuous optimization, computer science, game theory, and economics to develop efficient exact and approximation algorithms, and to understand the limits of computability.

Fundamental questions that arise when multiple individuals interact
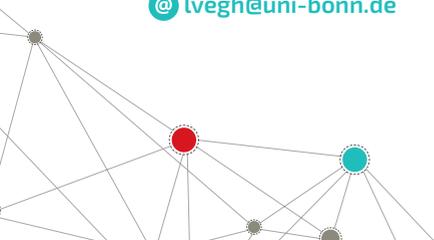
Argelander Professor for
Mathematics – Economics – Computer Sciences

Prof. Dr.
Florian Brandl

Florian Brandl studies fundamental questions that arise when multiple individuals interact in strategic situations. This research aims to shed light on the behavior of rational individuals in competitive economic settings such as markets or voting. He uses mathematical language to model and analyze these questions. In addition, methods from Theoretical Computer Science are helpful to treat emerging algorithmic issues.

@ fbrandl@uni-bonn.de

Florian Brandl's research focuses on Game Theory and Social Choice Theory, two areas in the broader field of Microeconomic Theory. Game Theory provides the basis for analyzing the behavior of rational individuals in interactions with others and applies in many economic settings. Social choice theory studies collective decision-making by multiple individuals, for example, through voting mechanisms. Within these areas, Florian Brandl is particularly interested in foundational game-theoretic issues, decisions that involve uncertainty, and the fair allocation of resources across multiple individuals. His work frequently uses the axiomatic method, which identifies axioms that decisions should satisfy and studies their implications.

TRA key figures 2020 – 2024
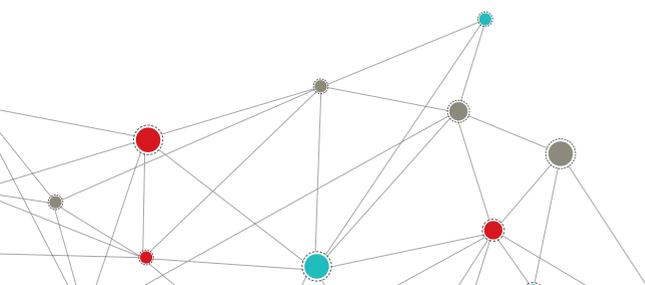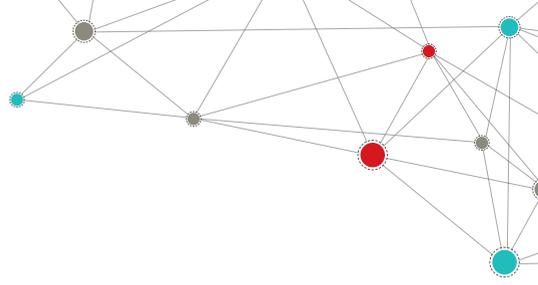
153

members

44

funded projects

33

networking events

€ 1.1 million

money spent

New Modelling Methods for Biological Cell Tissues

The TRA Modelling continuously supported emerging research topics at the University of Bonn. One of the most important developments was the establishment of the IRU Mathematics and Life Sciences (MLS). In 2019, Prof. Jan Hasenauer started as the first recruit in this area as an Associate Professor (W2) with tenure track. Prof. Hasenauer is an expert in data-driven computational biology, image-based modelling, computational data analysis, and software development, making his research profile an excellent fit for TRA Modelling. One of the first applications for TRA seed funding was initiated by Prof. Hasenauer in collaboration with Prof. Dr. Marieta Toma and Prof. Dr. Michael Hölzel of the University Hospital Bonn (UKB). These clinical partners contributed tissue samples, imaging data, and expertise in experimental pathology and oncology.

Starting in September 2020, TRA Modelling funded their joint project, which focused on establishing novel computational methods for spatially resolved deep profiling of biological tissues. The 12-month TRA funding was instrumental in strengthening the IRU MLS as well as fostering productive collaborations between the modelling groups at the University of Bonn and the experimental groups at the UKB. This successful project was pivotal in consolidating the Hasenauer Group for Computational Life Sciences at the IRU MLS. It also contributed to the subsequent acquisition of an ERC Consolidator Grant and a BMBF grant, as well as the appointment of Prof. Hasenauer as Schlegel Professor of the Faculty of Mathematics and Natural Sciences in 2022.

Symposium on High Performance Computing (HPC)

Scientists from all disciplines welcome „Marvin".

Many scientists at the University of Bonn have been eagerly awaiting the launch of the new mainframe computer "Marvin", which will significantly improve the local HPC capacities for all scientific disciplines. On October 20, 2023, the wait was over and TRA Modelling used the occasion of the official VIP inauguration ceremony of Marvin to extend a complementary invitation for a wide audience - from PhD students to experienced researchers. With the help of the broad scientific network of TRA Modelling, seven highly suitable speakers, experts and HPC users alike, could be won to give a talk. Prof. Dr. Estela Suarez and Prof. Dr. Thomas Luu (both Forschungszentrum Jülich), together with local speakers Prof. Dr. Peter Krawitz (University Hospital Bonn), Prof. Dr. Julian Klaus (Dept. Earth Sciences), Prof. Dr. Carsten Burstedde (Dept. Mathematics), Prof. Dr. Petra Mutzel (Dept. Computer Science), as well as Jan Steiner (University IT and Data Center) were able to demonstrate the various practical applications of HPC to multiple scientific questions. By covering the core topics of TRA Modelling, Mathematics and Computer Science, and application fields Life Sciences & Medicine, Geosciences and Physics, the symposium was very much in line with the TRA's mission to bridge the boundaries between disciplines. With ample time for discussion and networking, 60 participants took the opportunity to meet and gain insights into other research fields.

Integration of Algorithmics and Geodesy

With Support of TRA Modelling to the DFG AI Research Unit „AlgoForGe", CESOC and beyond

When I started as Professor for Computational Analytics at the University of Bonn in October 2019, the field of Geodesy was not yet one of my research interests, although my research has always been application-oriented. Soon after, I was involved in the formation of a group of scientists, that felt addressed by a DFG call with the objective of (1) closely link fundamental research in AI with a new partner field and (2) integrate the topic onto a local long-term research profile. Building on the long-standing close relationship between the Universities of Bonn and Cologne within the field of Geoscience, Geodesy was identified as a promising field of application for AI, so that both objectives of the call were met. In February 2020, Anne Driemel, Heiko Röglin, Jan-Henrik Haunert, Jürgen Kusche and I jointly with colleagues from the University of Cologne, Melanie Schmidt and Christian Sohler, started planning the proposal to the DFG.

"Besides financial support, also the positive feedback on our TRA application really helped us to move the project forward."

In order to strengthen our joint preliminary work in the field of Geodesy, it was very helpful to receive financial support from TRA Modelling by funding a Ph.D. position for 15 months.

To our delight, the DFG decided in June 2022 to fund our AI research unit FOR 5361 "AlgoForGe: Algorithmic Data Analytics for Geodesy", in which we study algorithmic challenges of fundamental AI problems in Geodesy, and develop new algorithmic data analysis methods and tools. Since our common preliminary work for the DFG proposal has been extra-ordinarily successful, the three founders of CESOC (Susanne Crewell, Astrid Kiendler-Scharr, and Jürgen Kusche) asked us in November 2020 to join. CESOC is a joint virtual institute of the Universities

of Bonn, Cologne, and FZ Jülich, which has been founded in October 2020 to support the successful application of Bonn to host the new location for the European Centre for Medium-Range-Weather Forecasts (ECMWF). CESOC focuses on physical, mathematical and biogeochemical modelling of the coupled Earth system in view of the development of a digital Earth model, and aims at close ties between geosciences and methods from Computer Science and Mathematics.

Overall, these developments were helpful for a planned joint Cluster initiative, which unfortunately was not invited to submit a full proposal in 2024. We are nevertheless confident that the new field of Algorithmic Earth System Science planned there will be established on the long run

and the cooperation of the Universities Cologne, Bonn, FZ Jülich, and the ECMWF will be continued successfully. For example, Bonn and Cologne are jointly planning for a semester in Algorithmic Earth Science in winter term of 2025/26. Our overall aim is to better integrate concepts from algorithmics in Theoretical Computer Science and Earth Observation in order to significantly improve our understanding and predictive capabilities of the rapidly changing Earth system at regional-to-local scales.

> *The encouragement to initiate new transdisciplinary research projects through the TRAs is a great benefit for the University of Bonn.*

Prof. Petra Mutzel, Chair of Computational Analytics

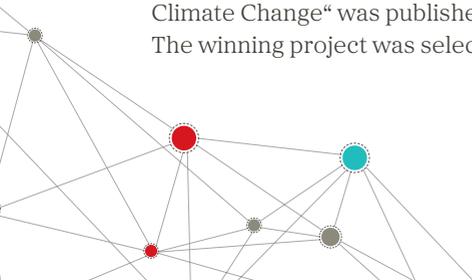# TRA Modelling and DETECT Jointly Support Early Career Scientist

In March 2022 TRA Modelling was approached by CRC 1502 DETECT "Regional Climate Change: Disentangling the Role of Land Use and Water Management" with a special kind of application, namely DETECT Speaker Prof. Dr. Jürgen Kusche and principle investigator Prof. Dr. Petra Mutzel proposed an award designed for members of TRA Modelling with interest in the field of Earth System Modelling. The awarded research project should than be seed funded by TRA Modelling and re-evaluated for envisaged follow-up-funding by DETECT. Furthermore, the awarded young scientist will have the chance to join DETECT in the 2nd funding phase (approval by DFG provided).

This clever idea was approved by the steering committee of TRA Modelling with a large majority in May 2022 and shortly after the Collaborative Research Award "Mathematics, Modelling, and Simulation for the Investigation of Climate Change" was published. The winning project was selected by a joint jury of steering committee members of TRA Modelling and DETECT, respectively, based on independent reviews by members of TRA Modelling.

With the project "Statistical Testing and stochastic processes for the Analysis of Modeled and observed Earth system Data – STAMPED" our awardee Dr. Jan Martin Brockmann (Institute of Geodesy and Geoinformation, IGG) aims to transfer a successful modelling approach from the realms of Geodesy to data relevant for DETECT. With the TRA funding until 2024 he was able to hire a research assistance and document several achievements of the running project. Today Dr. Brockmann is already listed as member of DETECT.

This example shows how flexible resources of TRA Modelling and cooperation with successful collaborative research consortia enables forward-looking planning for the consolidation of excellent research in Bonn and promotion of young scientists at the same time.
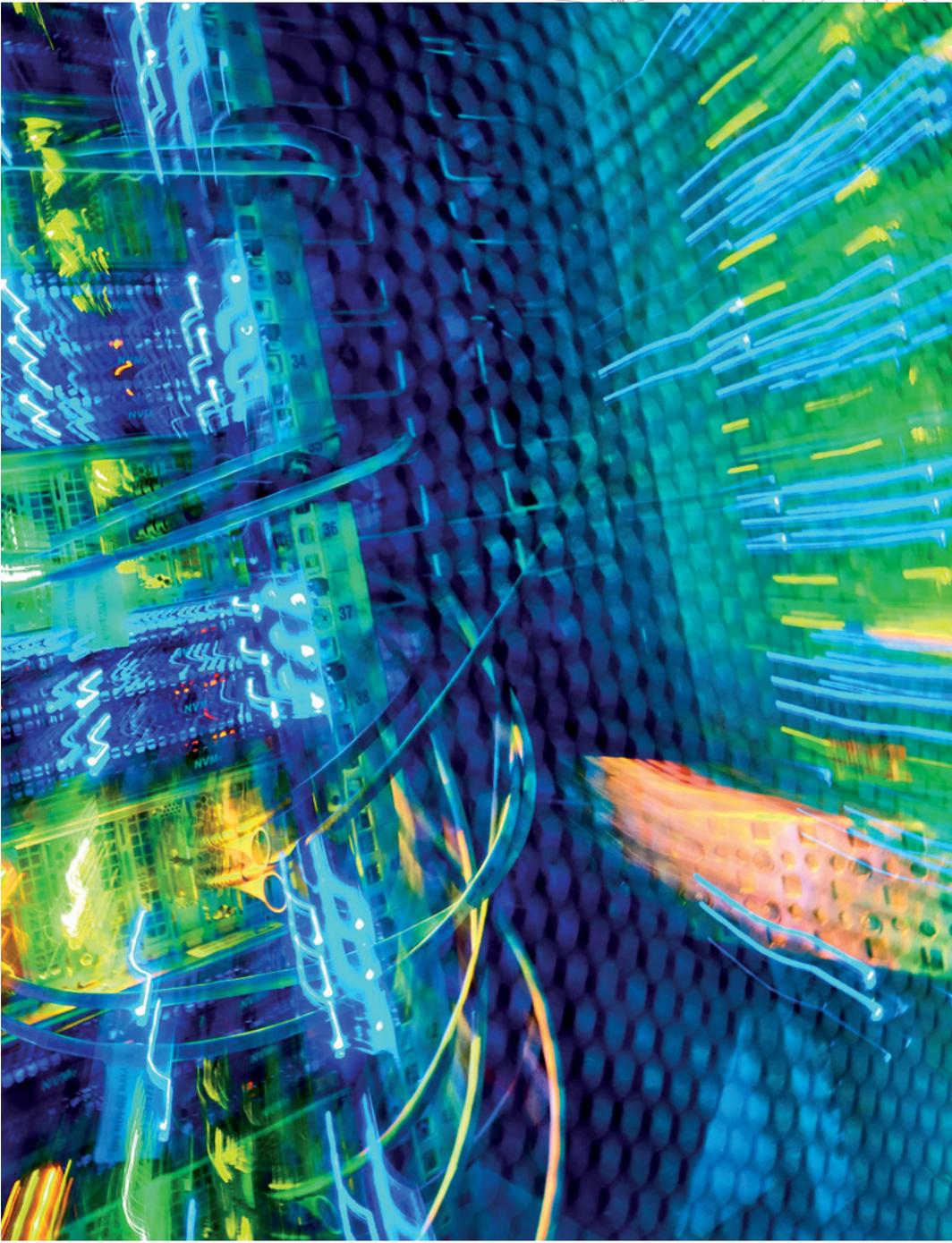
TRA spokespersons

Prof. Dr. Alexander Effland,
Institute for Applied Mathematics

Prof. Dr. Jürgen Gall,
Institute of Computer Science

TRA manager

Dr. Daniel Minge,
Staff Unit for Strategic Development
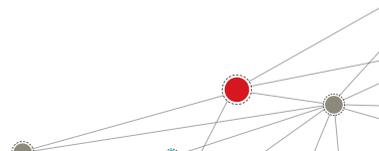and Quality Assurance

ex officio members

Prof. Dr. Valentin Blomer,
as Spokesperson of Excellence HCM

Prof. Sven Rady, Ph.D.,
as Head of the Department of Economics

Prof. Dr. László Végh,
as Hertz Chair of TRA Modelling

Prof. Dr. Walter Witke,
as Dean of the Faculty of Mathematics
and Natural Sciences

TRA
MODELLING

Professorial members

Prof. Dr. Anton Bovier,
Institute for Applied Mathematics

Prof. Dr. Jürgen Dölz,
Institute for Numerical Simulation

Prof. Dr. Anne Driemel,
Institute of Computer Science

Prof. Dr. Ulrike Endesfelder,
Institute for Microbiology and
Biotechnology

Prof. Dr. Lucie Flek,
Institute of Computer Science

Prof. Dr. Joachim Freyberger,
Institute of Finance and Statistics

Prof. Dr. Philipp Hieronymi,
Mathematical Institute

Prof. Dr. Matthias B. Hullin,
Institute of Computer Science

Prof. Dr. Petra Mutzel,
Institute of Computer Science

Prof. Dr. Heiko Röglin,
Institute of Computer Science

Prof. Dr. Catharina Stroppel,
Mathematical Institute

Prof. Dr. Kevin Thurley,
Institute of Experimental Oncology

Status group representative

ACADEMIC STAFF

Dr. Magdalena Balcerak Jackson,
Managing Director HCM

Dr. Sven Mallach,
Institute of Computer Science;
deputy position Dr.-Ing. Jan Martin
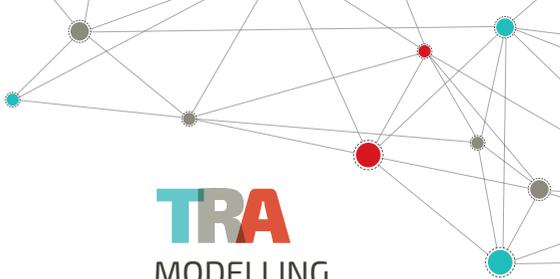Brockmann, Space Geodesy Group, IGG

STUDENTS

Lillian Witters,
Student Council Mathematics;
deputy postition Leo Papenhausen

Christoph Geron,
Student Council Computer Science;
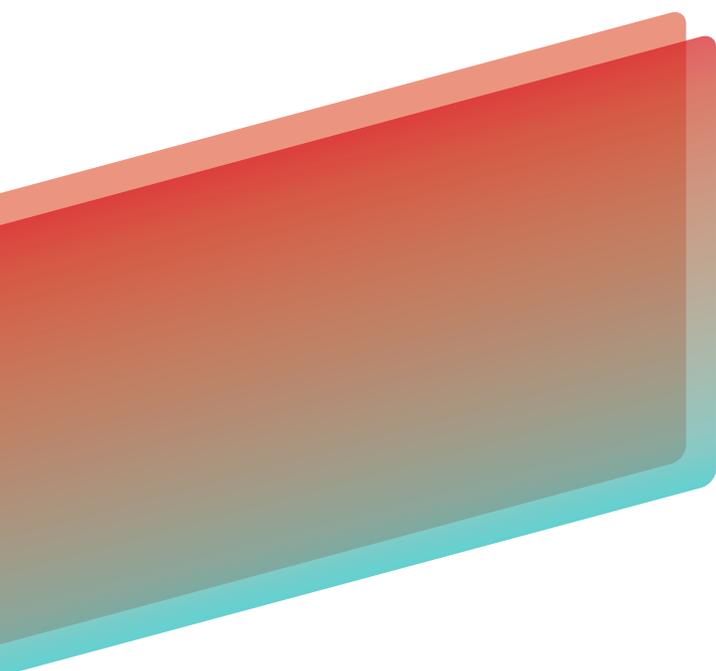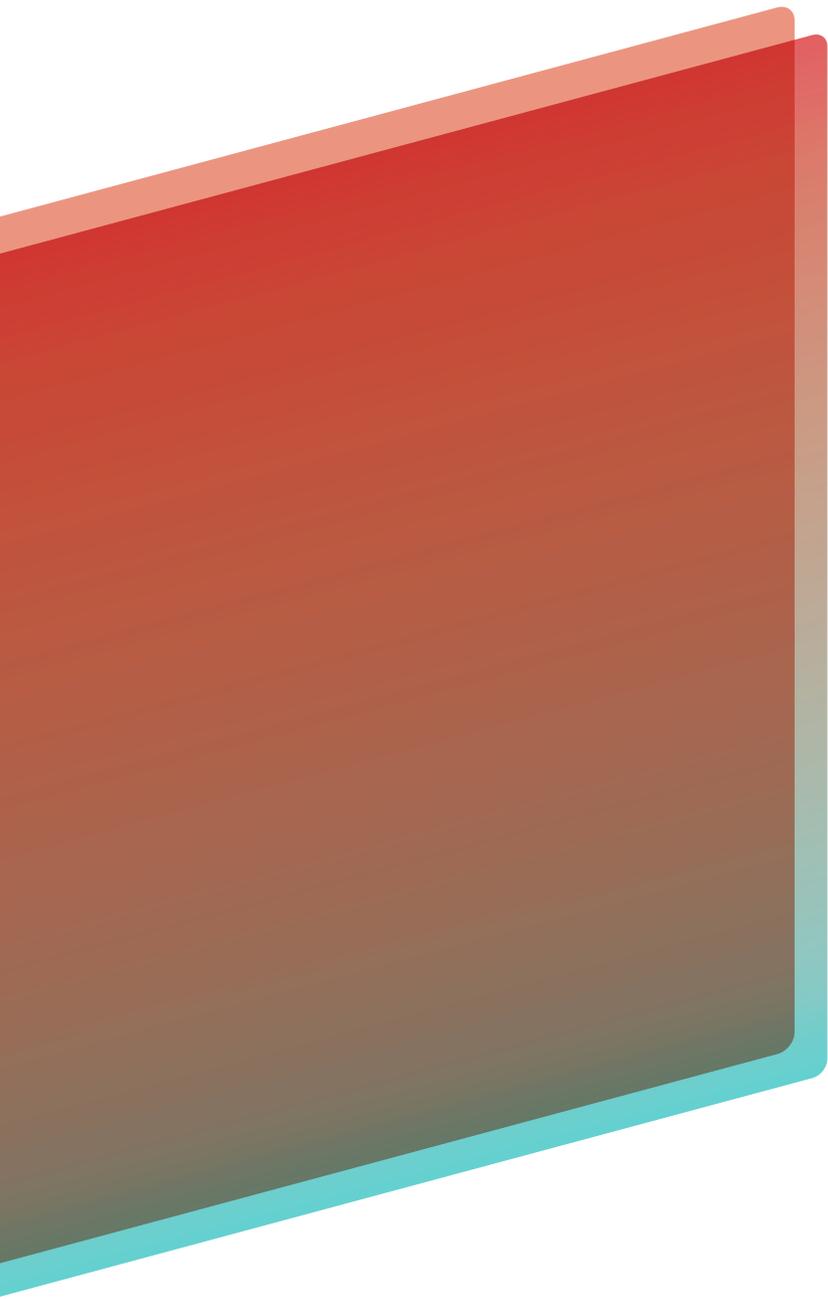deputy position Felix Roth

TECHNICAL AND ADMINISTRATIVE STAFF

Anna Kessler, Mathematics
deputy position Daniela Schürheck,
Computer Science
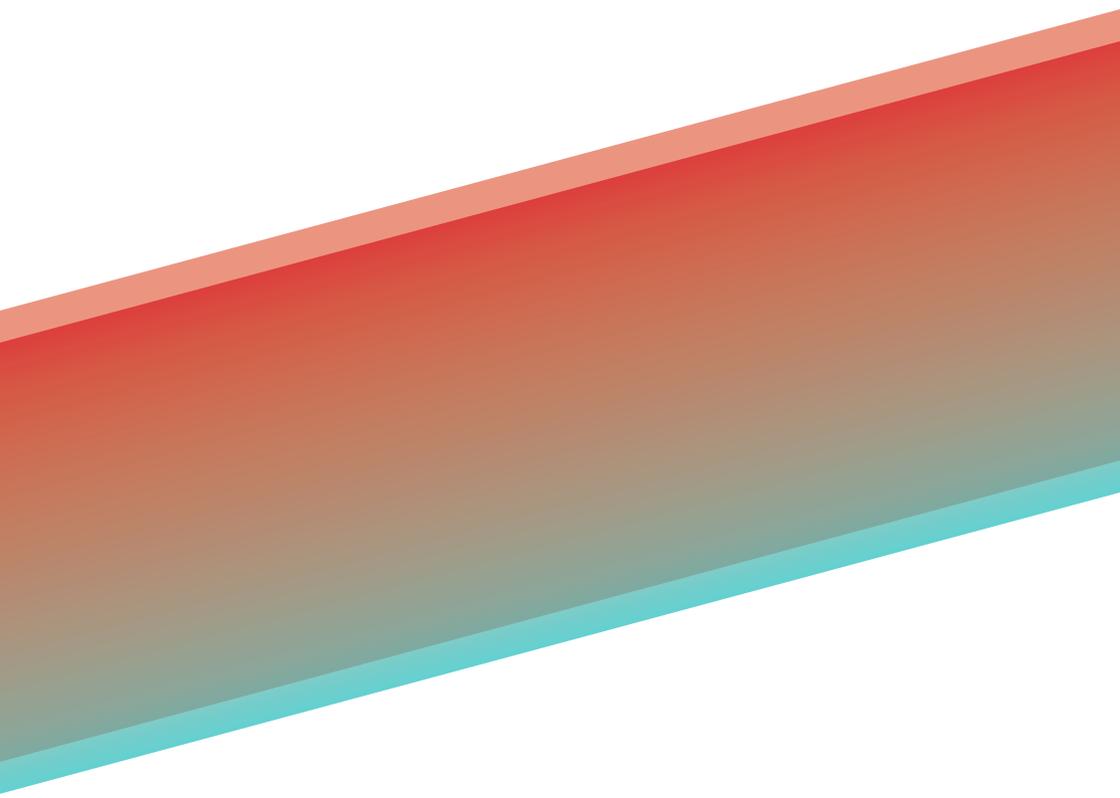
TRA Mathematics, Modelling and Simulation of Complex Systems

tra1@uni-bonn.de,
uni-bonn.de/en/tra-modelling

UNIVERSITÄT BONN