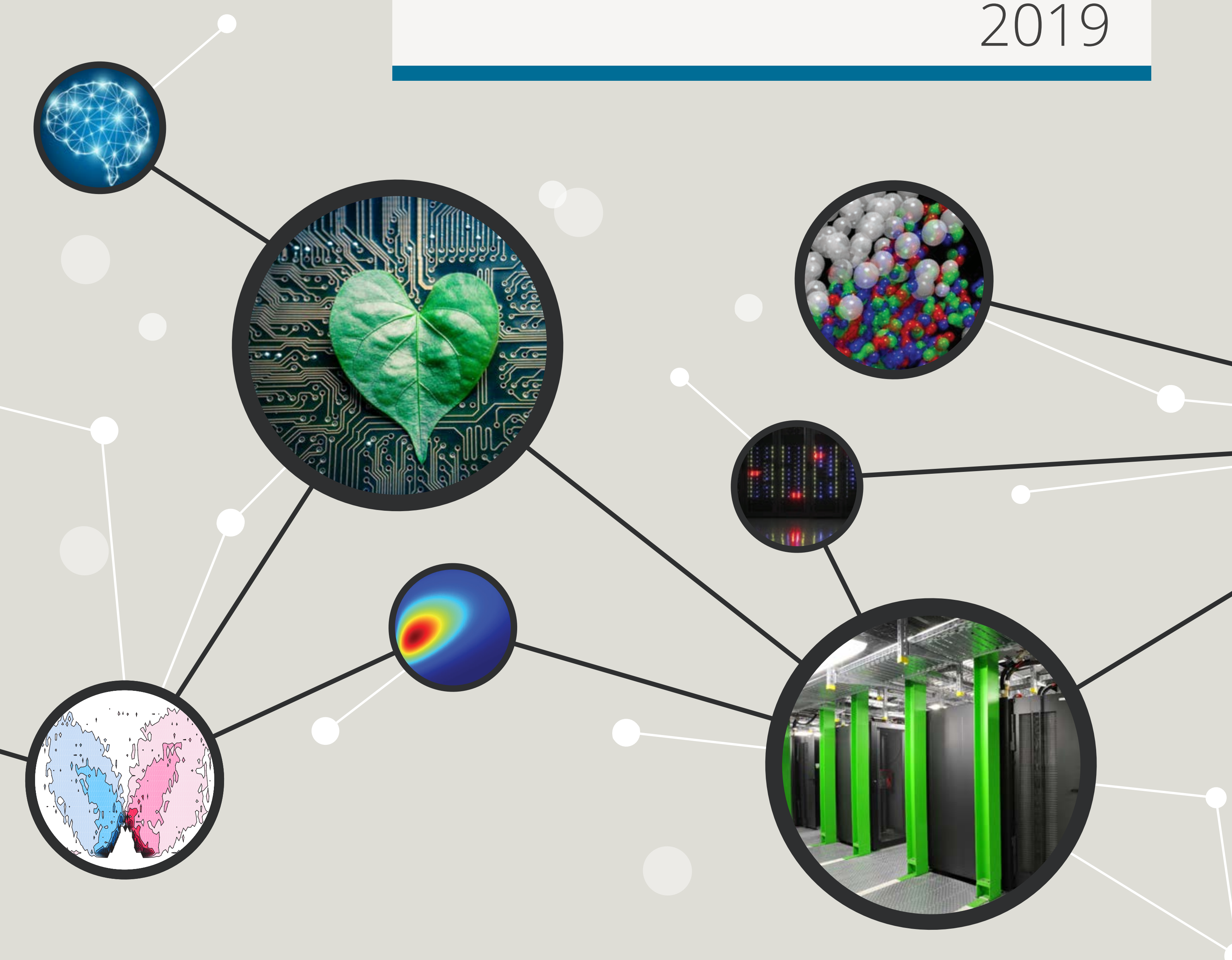
FIAS Frankfurt Institute
for Advanced Studies

2019



Content

FIAS

science for the reality of tomorrow

Dear colleagues,
Dear friends and supporters of our science,
Dear knowledge seekers,

We as FIAS community look back on a very exciting year 2019, in which many decisions for the next years were made. As a place of creativity and courage to tread new and unique paths, we presented the FIAS Award for Lateral Thinkers for the first time, namely to Sabine Hossenfelder, a lateral thinker in the tradition of the FIAS, whose work shakes up the existing research dogmas. As a place of interdisciplinary and international cooperation, we founded the Xidian-FIAS International Joint Research Center in October in the presence of the Chinese Minister of Science and Technology Wang Zhigang. The Xidian-FIAS is a new format for research and application of artificial intelligence methods with international partners, and brought it to life in the Giersch Summer School, which is sponsored by our long-time patron STIFTUNG GIERSCH.

As a place of integration of theoretical research with the experimental approaches of our cooperation partners at the university and in the surrounding institutes, for example the Max Planck Society, Helmholtz Association, or Leibniz Association, we have successfully acquired the LOEWE Project CMMS, which will become the cornerstone of Life Sciences lighting in the coming years. And, in this context, we have also been able to win three fantastic new colleagues through the support of the Quandt Foundation, who will certainly question one or the other dogma with their work in the coming years and thus contribute to new groundbreaking insights. And we are doing all this with the help of third-party funding or donations from donors, whom we would like to thank here once again, because without their commitment we would not be able to look backward on such a successful 2019 and forward to such an optimistic future!

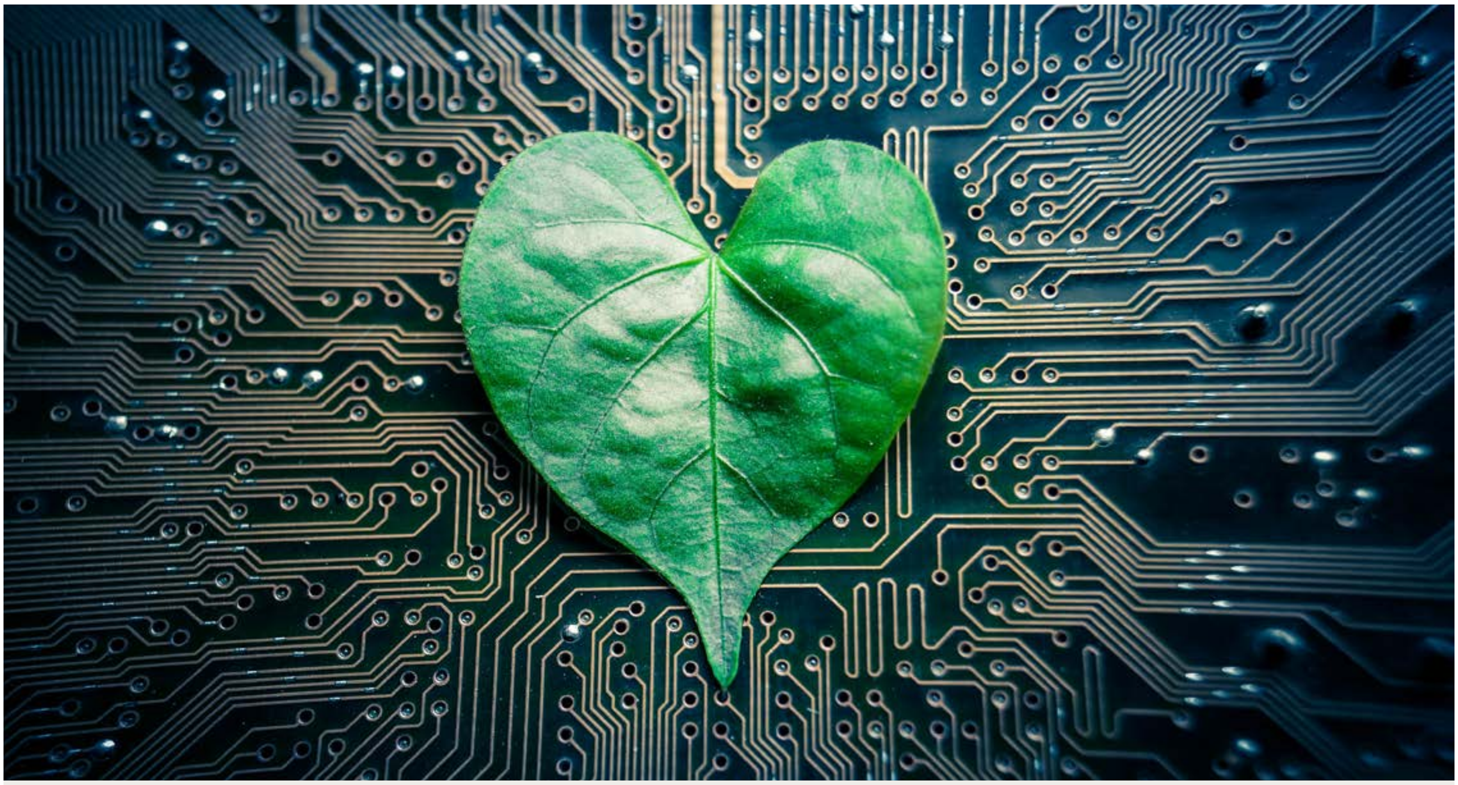
I hope you will enjoy experiencing exciting questions and creative approaches while leafing through our annual report.

On behalf of all FIAS members

Enrico Schleiff

Chairman of the Board

Highlights 2019



LOEWE CMMS

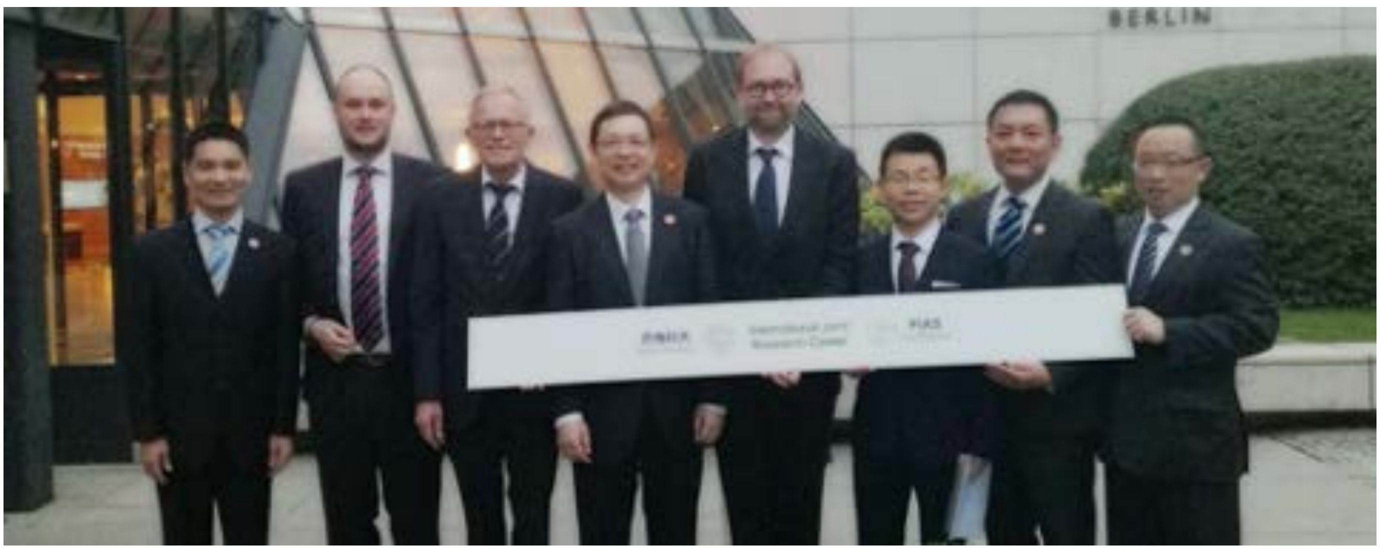
As a place of integration of theoretical research with the experimental approaches of our cooperation partners at the university and in the surrounding institutes, for example the Max Planck Society, Helmholtz Association, or Leibniz Association, we have successfully acquired the LOEWE Project CMMS, which will become the cornerstone of Life Sciences lighting in the coming years. CMMS is the Frankfurt centre for multi-scale modelling, analysis and simulation of biological processes. The long-term goal of CMMS is a comprehensive understanding of both simple molecular biological processes, such as the mode of action of an enzyme, as well as the complex behaviour of organisms. Such an understanding is the basis for the adaptation of cell functions for biotechnological use as well as for the development of biomedical, pharmacological and agricultural applications. Advances in the development of high-resolution methods for the atomistic description of molecules, cells and cell systems using cryo-EM and light microscopy provide insights into molecular mechanisms and processes. By integrating this information into models and simulations, basic mechanisms and causalities are identified. This requires new technical, algorithmic and informatic solutions to overcome the scale constraint and the prediction of missing information in experimental data sets.

XF - International Joint Reserch Center

In October 2019, during the Sino-German Conference for Science, Technology, Innovation and Cooperation in Berlin, representatives of Xidian University and FIAS signed the founding documents of the XF-IJRC.
The signing ceremony was held in presence of the chinese minister for science and technology Mr. Wang Zhigang. Minister Wang applauded the initiative for scientific cooperation between the two institutes and expressed his wish for a successful joint lab.

After the signing ceremony President Yang, of the Xidian University, and his delegation visited FIAS to greet the FIAS research fellows and students who are eager to work in collaboration with their Xidian colleagues. Since a proposal to establish the 'Xidian-FIAS Joint Research Center' (XF-JRC), which was initiated between the FIAS 'Deepthinkers'-AI group and President Zongkai Yang, during a previous visit to FIAS in November 2018, both parties have been working intensively over the past few months to exchange ideas and opinions about the realization of the XF-JRC.

The proposal followed a successful summer school on "Horizons of Industry 4.0 in Germany and Artificial Intelligence", organized by FIAS for Xidian University students in 2018, at which the students attended lectures by FIAS Fellows Prof. Dr. Jochen Triesch, Dr. Kai Zhou and Dr. Jan Steinheimer.
Prof. Dr. Enrico Schleiff, as representative of the FIAS board of directors, expressed his strong support for the proposed Joint lab together with Xidian.
“The Joint Lab will be part of the FIAS strategy to strengthen research on artificial intelligence and its application in interdisciplinary scientific research and development. Within its function it will strongly promote international research cooperation.”



Endowments 2019

As a foundation, the FIAS depends on the favor of private and corporate donors. Therefore we are pleased to have received donations again in 2019.

The **GIERSCH FOUNDATION** supported the FIAS in 2019 with almost 350,000 Euros. It again made it possible to award 6 scholarships, thus making an outstanding contribution to the training of excellent young scientists. In addition, the Giersch Excellence Awards again supported the best doctoral students.

Already for the 4th time she supported the Giersch International Symposium, in the course of which the Nobel Laureate Chrisitne Nüsslein-Volhard was awarded the FIAS Senior Fellow Laureatus, furthermore the Giersch Endowed Professorship, established in 2016, was supported.

Samson AG made it possible to establish research in the field of artificial intelligence through a project donation of 300,000 Euros.

The **Quandt Foundation** enabled the settlement of three junior research groups as Research Fellows. In addition, it supports the Quandt Foundation Professorship and has supported the FIAS 2019 with a total of 100.00 Euros.

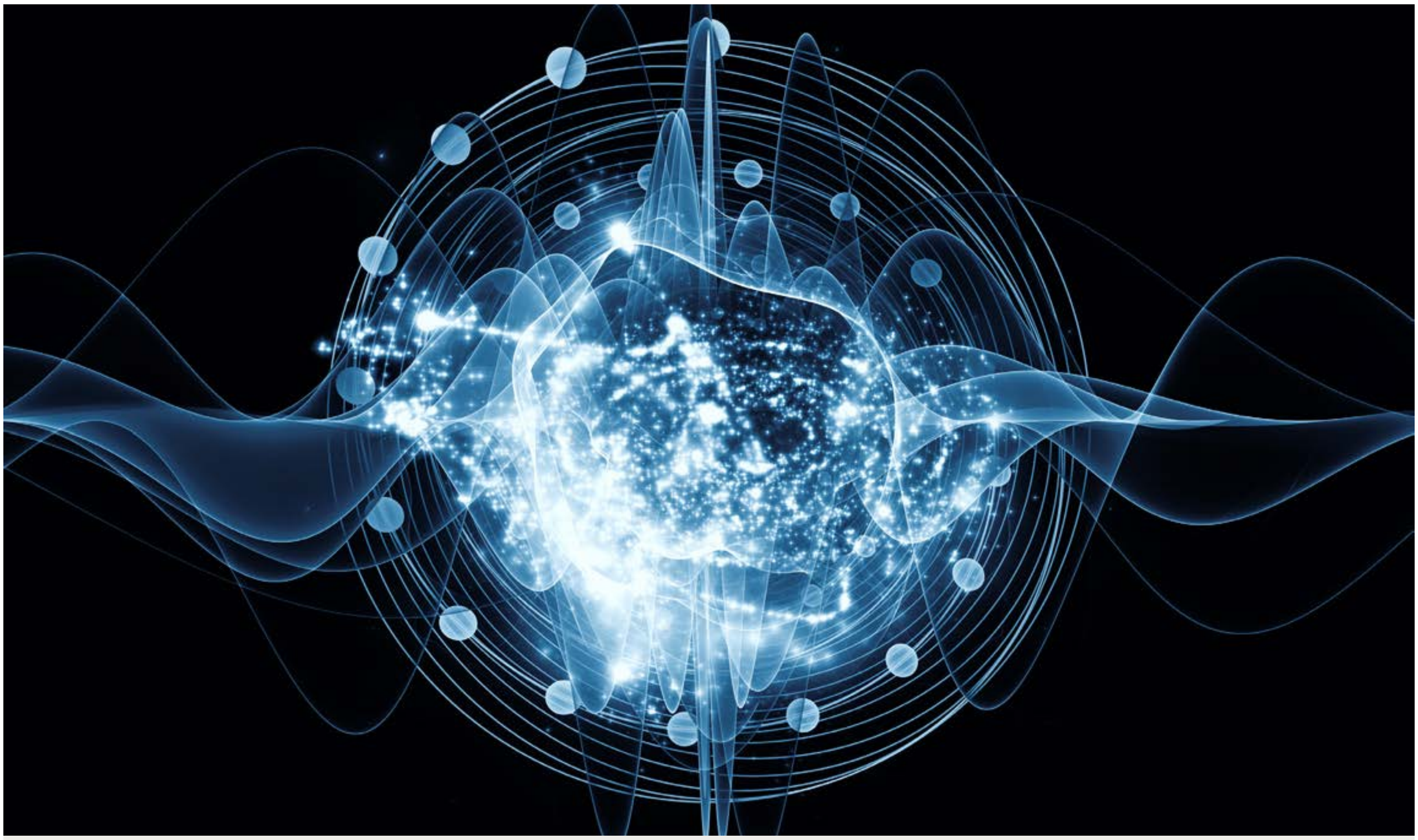
Another research group is made possible by the **Alfons and Gertrud Kassel Foundation**, which also donated 100,000 Euros.

The **Fueck Foundation** donated about 50,000 Euro through the Walter Greiner Gesallschaft and thus made several scholarships possible.

The **Polytechnic Society** provided 45,000 Euro to finance a postdoc, including travel and materials.

We sincerely thank the donors for their contribution!

Theoretical Sciences

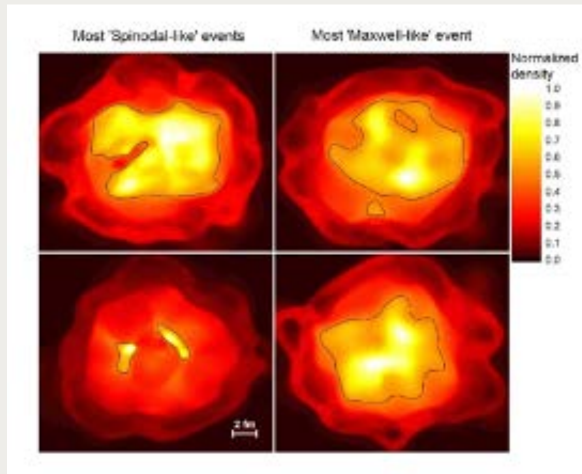


Methodological research in the field of AI is already proving to be groundbreaking in the area of Theoretical natural sciences for the treatment of problems in theoretical physics. One focus is on high-energy and heavy ion research and related astrophysical questions, such as the investigation of neutron star collisions and the phase structure of the hot, dense matter produced there, as well as field theory. The AI methods developed at FIAS are also applied for the description of properties of condensed matter, of hydrodynamic and electrodynamic flow fields in large networks and for sustainable energy research. Furthermore, the FIAS initiated the methodological transfer to geophysics, e.g. for the description of seismic quakes. The FIAS also contributes its interdisciplinary methodological knowledge, e.g. to evaluate data from atmospheric and climate research.

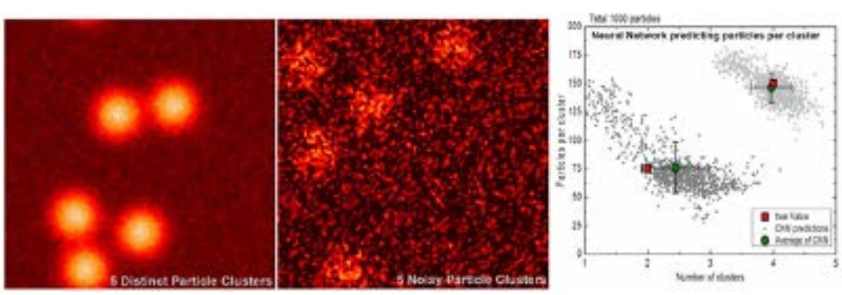
AI for FAIR by Dr. Jan Steinheimer

Heavy ion collisions at relativistic beam energies are an abundant source of particles created by the strong interaction. These particles and their correlations, in principle, carry information on the properties of matter in which they were created. Recently, it was suggested that a new approach based on modern AI and machine-learning methods may offer a new promising venue to characterize this information. As modern neural networks are powerful tools for extracting information from complex datasets, it was suggested to use them to circumvent the biased `handcrafting' of observables. Instead, the neural network should itself select the appropriate features within the data which are e.g. most sensitive to the properties of the equation of state of the system created.

In the present work we have used deep neural networks to identify the coordinate space clumping, which appears during the spinodal decomposition, of a first order phase transition of dense and hot nuclear matter. Using the deep learning we can show that a phase transition during the collision of two nuclei, as observed at the FAIR facility at GSI, leaves strong characteristic imprints on the system. The characteristic clusters as identified by the AI-algorithm are shown on the left hand side of the figure below, which shoes the density distribution of the hot fireball in such a heavy-ion collision at FAIR.



A challenge for the measurement of such distributions in real detectors, at the CBM experiment, is the large noise due to the limited number of particles measured. The appearance of noise in observations is a widespread phenomenon not only limited to high energy physics. As an example the figure below shows how 5 clusters of particles would show up in a measurement with small noise or large noise. The extraction of correlation parameters would be much more difficult in the noisy case, even for an AI algorithm.



The current focus in this project is to study how Deep-neural-networks can be used to identify such clusters in the presence of noise and determine and quantify the limits of these models to make their predictions more reliable. In this way we intend to make the AI models, which are already widely used for such tasks, more interpretable and the results understandable in a quantitative way.

Project:

This collaborative Project of FIAS Fellows Jan Steinheimer, Horst Stöcker, Nan Su and Kai Zhou, is currently ongoing and part of two projects, one funded by BMBF (ErUM-data) and one research exchange with Lawrence Berkeley National Laboratory funded by the DAAD. In addition part of this work is funded by a generous grant of the SAMSON AG.

Publications 2019:

- JHEP 12 (2019) 122
- Phys.Lett.B 790 (2019) 557-562
- Phys.Rev.C 101 (2020) 3, 034904

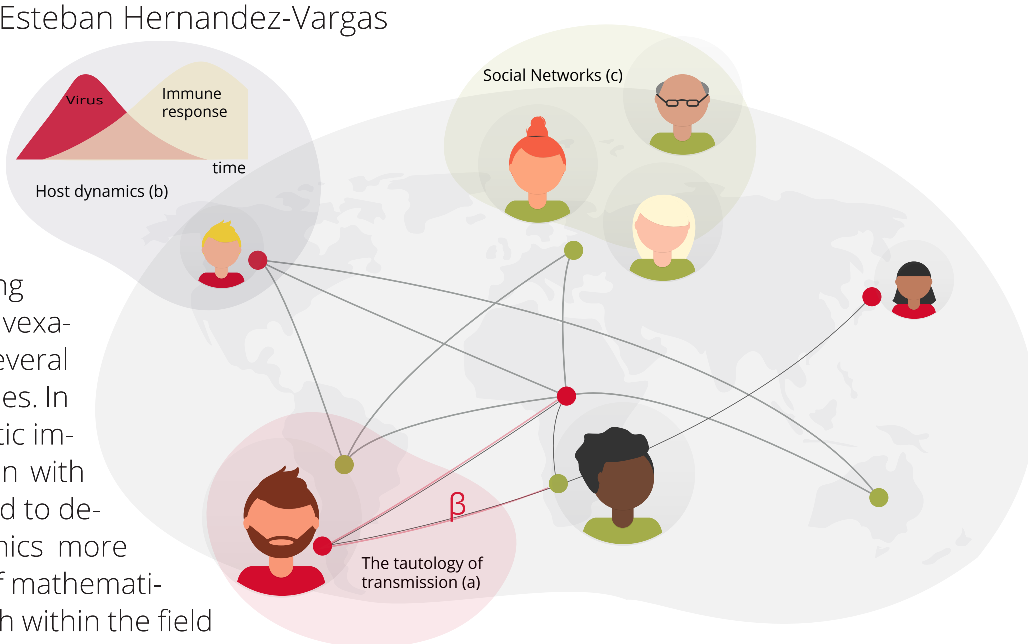
Theoretical Life- & Neuro Sciences

Biological and medical research depends on theoretical approaches to the analysis of complex data structures and the description of highly interconnected biological processes. In the field of theoretical life sciences, the FIAS develops methods taking into account the different scale levels for modelling biological systems and in the interdisciplinary theoretical neurosciences. The standardized integration of theoretical methods is also implemented in medical and pharmaceutical research, such as cancer research and drug development. In all fields, theoretical and experimental approaches and methods for the analysis of heterogeneous data sets are (further) developed - for the standardization of data acquisition and processing, for the development of detailed multi-scale models and their simulation using high-performance computing resources and the application of AI methologies. The FIAS follows the principle of integrative experiment design, which integrates experimental and theoretical competences equally. The FIAS also focuses on the transfer of its theoretical competencies to the experimental research community.

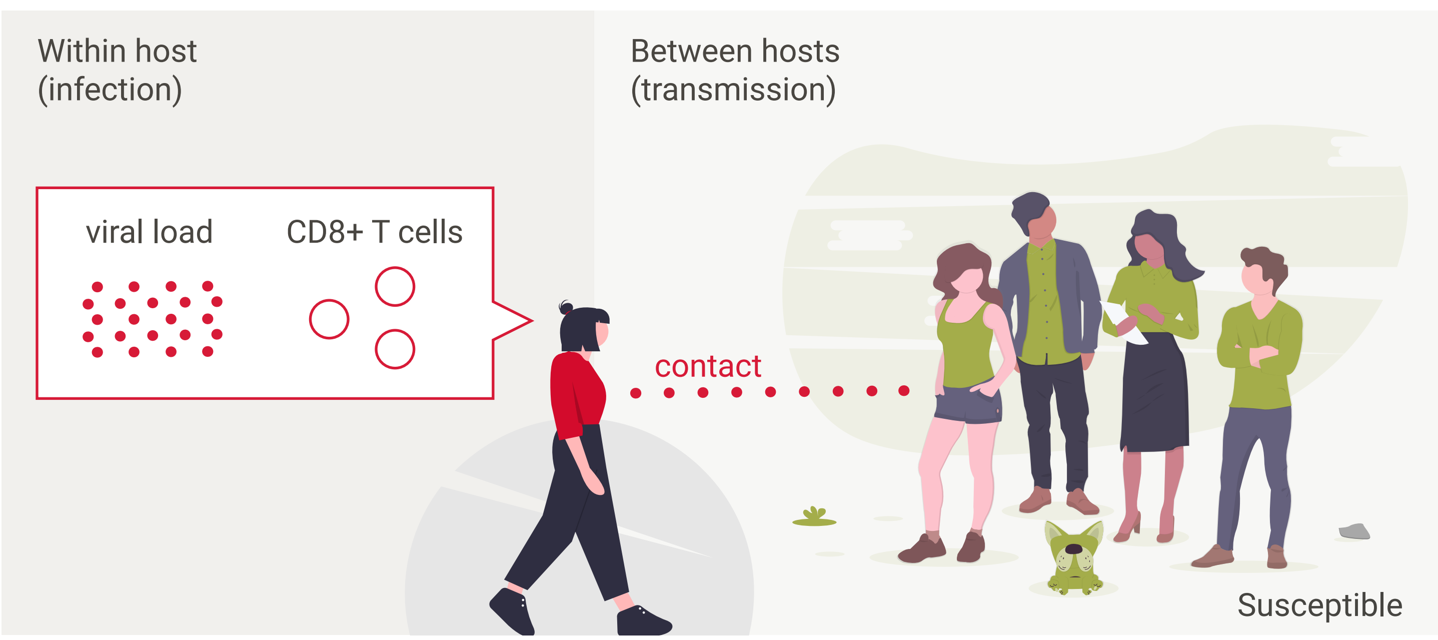
A new view of multiscale stochastic impulsive systems for modeling and control of epidemics

by Dr. Esteban Hernandez-Vargas

Infectious diseases are latent threats to humankind - killing annually millions worldwide. Disease transmission modeling and control remain a central vexation for science as it involves several complex and dynamic processes. In this paper, multiscale stochastic impulsive models in combination with contact patterns are presented to describe outbreaks and epidemics more accurately. The new families of mathematical models open up a new path within the field of control theory with long-term impact and ample opportunities to control epidemics. Ultimately, multiscale models are introduced as a potential tool to provide in the field of epidemiology with a new vision, drawing on the philosophy that social behavior has an underlying shape and that shape could impact epidemic dynamics.



a) The transmission process often is summarized by one parameter β. Each susceptible node, in green, can become infected from the infected neighbour, in red.
b) Host transmission can be based on the host infection dynamics.
c) Social interactions can reveal contact disease transmission.



A disease model is usually restricted to one of the following scales: within a host (left) and between hosts (right). Our multiscale model considers both scales, by focusing on the interaction of the virus and immune response (e.g., CD8+ T cells) within an infected host, and direct contact between susceptible and infected individuals

Publication:

E.A. Hernandez-Vargas, A.Y. Alanis, J. Tetteh.
A new view of multiscale stochastic impulsive systems for modelling and control of epidemics. Annual Reviews in Control. 2019

Computer Science & AI Systems

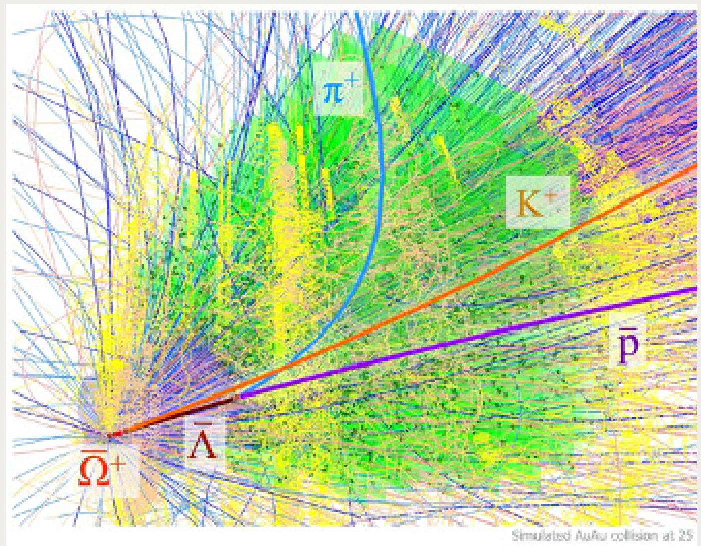
In the area of Computer Science & AI Systems, the already established work in the field of GREEN-IT is complemented by strategies of quantum computing and AI. Highly efficient computer architectures and program libraries are developed. In the past, computer architectures designed at FIAS achieved top positions in the world-wide ranking list for energy-efficient computers (Green500). The patented, highly efficient computer center architecture also allows a drastic reduction of construction costs. The use of GPU-based systems provides an ideal basis for the implementation of AI algorithms. The areas of application cover a very broad spectrum, ranging from tumor diagnostics to elementary particle physics and industrial problem solving. Currently, the existing systems are being expanded by a quantum computer and the necessary research. The developments in these areas will also find applications in the social, natural and life sciences.

Real-Time Event Reconstruction and Analysis in CBM and STAR Experiments by Prof. Dr. Ivan Kisel

The basic stage in processing of data from heavy ion collisions is the search for particle trajectories in the detector system. This is usually the most time consuming step, which can take up to 75% of the total processing time. In order to work at this stage, we developed an algorithm based on the cellular automaton (CA) method. This approach is now becoming a standard for all modern experiments in high energy and heavy ion physics. The very idea of the algorithm takes its roots from modeling the interaction of cells in biological systems. Parallelism and local character of such systems turned out to be successful in creating algorithms used on modern parallel computers, which allowed to obtain a significant (by several orders of magnitude) reduction in the time of searching for particle trajectories. In 2019 the work was carried out to improve the efficiency of the CA algorithm in search for low-energy particles, which due to its low velocity of flight leave in the detectors complex trajectories in an inhomogeneous magnetic field. Such particles are also subject to high energy losses when passing through the detector material, which requires careful statistical accounting. Particle parameters are reconstructed using the Kalman filter (KF) method. The use of CA-based search algorithms allows increasing the efficiency of particle reconstruction by 10-20% compared to conventional algorithms.

Particular attention was also paid to the further development of the KF Particle package for searching and reconstructing short-lived particles which, having a short lifetime, usually do not reach the detector system and are therefore reconstructed only through their daughter particles into which they decay. To work online, the package implements a search for more than 150 types of such short-lived particles. In addition to the high speed required for online operation, the package is also highly efficient. So its application to real data showed that it finds about 2 times more particles than traditional algorithms used in the STAR experiment.

To analyze the data in the final stage of processing, when all the particles have already been reconstructed, we are developing an artificial neural network (ANN) to determine the characteristics of the heavy ions collision itself. The application of the network we developed to the simulated data of the CBM experiment has shown that the network finds collisions with the formation of quark-gluon plasma with an efficiency above 93%.



A simulated collision in the future experiment CBM at FAIR

In 2019, it was shown that the data processing and analysis algorithms for the CBM experiment we are developing are of high quality and speed. Our work in the STAR experiment as part of the FAIR Phase-0 program has led to a full data reconstruction in the STAR experiment using our FLES algorithms developed for the CBM experiment. In addition, working in the conditions of the running experiment, the FLES package is complemented in turn by the STAR experiment algorithms for calibration and alignment of detector systems, as well as online data monitoring. These algorithms will be further migrated and adapted for use in the CBM experiment for real-time operation in the future on the line with the FAIR accelerator.

Publication:

Prof. Dr. Ivan Kisel has Hirsch-Index h=77. In 2019, he participated in 87 publications in peer-reviewed journals, including Nature Physics (impact factor 21.797). In the same year, 2,758 citations of publications with his participation were made.

Events

A delegation from China joined the Giersch International Symposium.

Giersch International Symposium

Modern methods of machine learning, especially deep-learning, are becoming more important for many scientific research fields. Not only in experimental sciences, where huge amounts of data can be accumulated, but also in fundamental sciences the application of AI-based algorithms is rapidly developing. The aim of this fourth 'Giersch International Symposium' was to bring together specialists on AI, particularly on applications of AI in fundamental sciences.

In particular the fields of life-science, neuro science and physics were represented as they are some of the main research areas of FIAS. But, serving FIAS interdisciplinary focus other fields of research will be covered. The Symposium took place at FIAS from November 18th to 22nd. During this week invited speakers from around the world came together and discussed the potential of using methods of artificial intelligence in fundamental research.

As always, one of the main objectives of the conference series was to give young scientists the opportunity to exchange ideas with top-class scientists and to expand their knowledge in a special field. For this reason, in addition to the conference talks, lectures for graduate and PhD students were offered in the afternoons as well as scientific discussion and exchange between the participants.

The "Giersch International Symposium" was the fourth event of this conference series facilitated by a generous donation by the STIFTUNG GIERSCH.

Ernst Strüngmann Forum

As in previous years, FIAS was the location for events by the Ernst Strüngmann Forum. In three workshops, international scientists from various disciplines were able to exchange ideas on current topics and work on new concepts. The topics in 2019 were “Deliberate Ignorance: Choosing Not to Know,” and “Intrusive Thinking across Neuropsychiatric Disorders”.

NetAllok Workshop 2019

The members of the NetAllok joint project met at FIAS in May. The aim of this research project is to investigate the current and future use of the electricity grid in the context of the ongoing energy system transformation and to methodically determine a systemically useful allocation of short and long-term grid costs.

IMOL2019 – Fourth International Workshop on Intrinsically Motivated Open-ended Learning

From July 1th-3th, 2019 IMOL 2019 was held at FIAS. Following previous editions, IMOL 2019 allowed to further explore the promise of intrinsically motivated open-ended lifelong learning in robots and artificial systems.

Baltic-Nordic Courses on Neuroinformatics

The Interdisciplinary Course was about understanding modeling at different organizational levels of the brain, from individual neurons to microcircuits and networks. The focus was on the differences between healthy and diseased brains.

The participants learned about the comparative and morphological modeling of synapses, dendrites and neurons as well as the simulation of local field potentials.

Participants of the summer school on science communicationat FIAS working on their project.

Computational Connectomics: Project Meeting

The team of the project SPP2041 Computational Connectomics met at the beginning of October for a project meeting at FIAS. The goal of the project is to obtain a comprehensive description of the interconnection of all components of the brain. In order to gain maximum benefit from the new technological developments, the refinement of experimental methods must be accompanied by corresponding theoretical and computational developments.

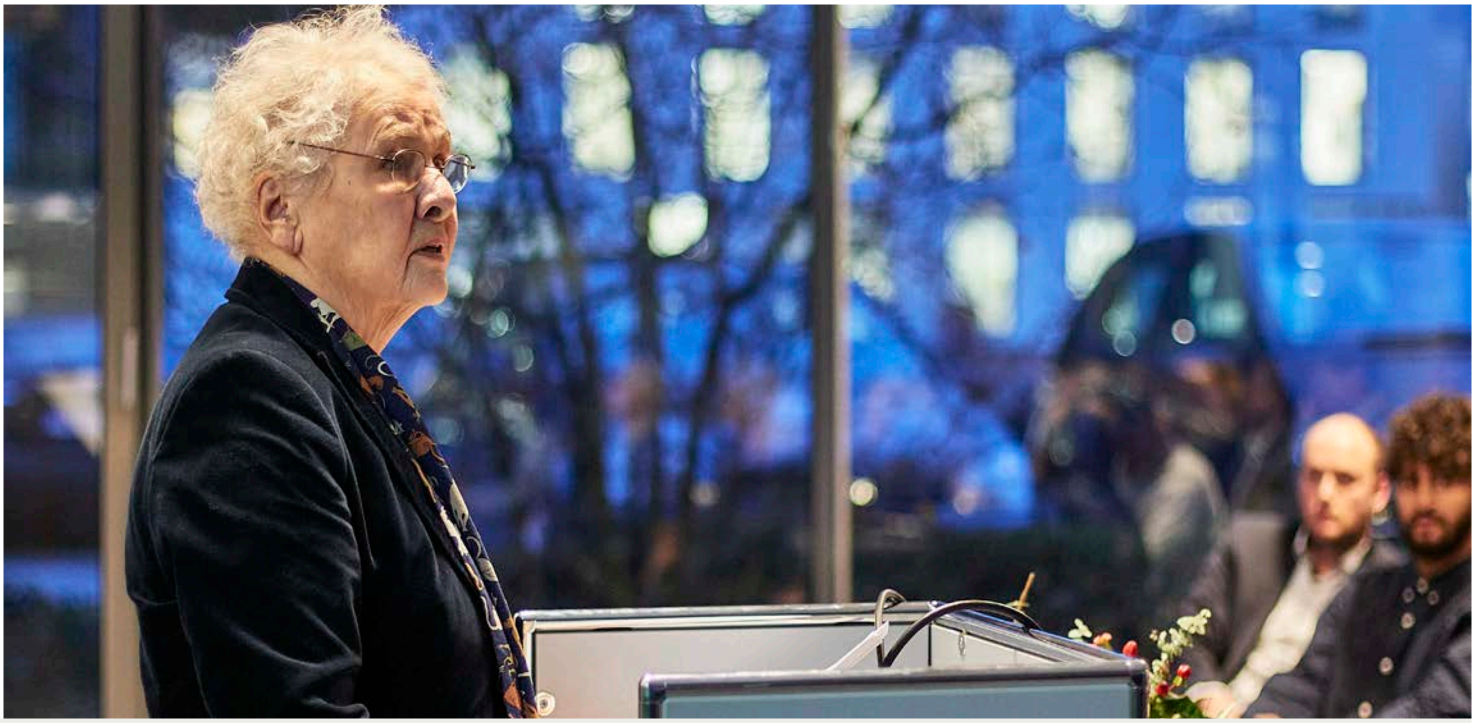
Joint Symposium FIAS and CEF 2019

Together with the Cluster of Excellence Frankfurt (CEF) a joined symposium was held on October 25 and 26 2019. Discussed topics were: “HPC Applications in Life Sciences”, “Simulation of Biological Systems”, “Methods of Multiscale Modelling in Life Sciences” and “Pharmacological probe development and characterization by AI methods”.

DAAD Summer School at Science Communication

Within the framework of the summer school, various projects in the field of science communication were developed and presented to the public. At the same time, a project in the field of digital science communication was realized, although the details were only worked out by the participants at the beginning of the summer school.

Awards &Public Relations



Prof. Dr. Christiane Nüsslein-Volhard was appointed as FIAS Senior Fellow Laureate by FIAS and the STIFTUNG GIERSCH at a ceremony during the Giersch International Symposium.

Senior Fellow Laureatus Christiane Nüsslein-Volhard

On November 21, 2019, a ceremony was held to mark the appointment of Prof. Dr. Dr. h.c. mult. Christiane Nüsslein-Volhard to FIAS "Senior Fellow Laureatus". This honorary award is given to outstanding international scientists who are not only distinguished by their excellent research work, but are also committed to the scientific community.

The Director and Scientific Member at the Max Planck Institute of Developmental Biology Christiane Nüsslein-Volhard has discoverd genes that control development in animals and humans, and has demonstrated morphogen gradients in the fly embryo. For this she has received a number of awards and honors, among others the Albert Lasker Medical Research Award, New York (USA), the Prix Louis Jeantet de Médecine, Geneva (Switzerland), the Ernst Schering Prize, Berlin (Germany), and the Nobel Prize for Medicine or Physiology in 1995.

The Hessian Minister for Science and Art, Angela Dorn, visits the FIAS exhibition at the Hessentag.

Hessentag 2019 in Bad Hersfeld

As part of the exhibition "Hands-on Research", Dr. Sascha Vogel's team presents science, especially FIAS research, in a hands-on exhibition where visitors can operate a particle accelerator, learn how algorithms work and experience what a vacuum does to a chocolate marshmallow. In cooperation with the initiative "Hessen schafft Wissen" (Hesse creates knowledge), the exhibition travels through Hesse and is presented in schools, at the annual Hessentag (with up to 30,000 visitors!) and at the Frankfurt Book Fair. The highlight in 2019 was the "Escape Room" designed by the FIAS team espacially for the Hessentag, which provided an innovative insight into the world of science and was very well received.

Dr. Sabine Hossenfelder, Research Fellow, has been awarded with the FIAS AWARD FOR INNOVATIVE THINKING 2019

With this award, FIAS wants to set an example that innovative ideas are more than ever necessary to secure the development capability of science and to preserve science as a source of ideas for social developments. And FIAS would like to use this prize to strengthen the courage of young scientists to think creatively and scientifically differently and to think beyond their own disciplines - not only at FIAS. It is precisely these ideas that are often highly controversial, difficult to publish or so far ahead of their time that they are regarded as "not relevant" according to classical short-lived citation criteria.

Sabine Hossenfelder with laudatory speaker Horst Stöcker and chairman of the board Enrico Schleiff

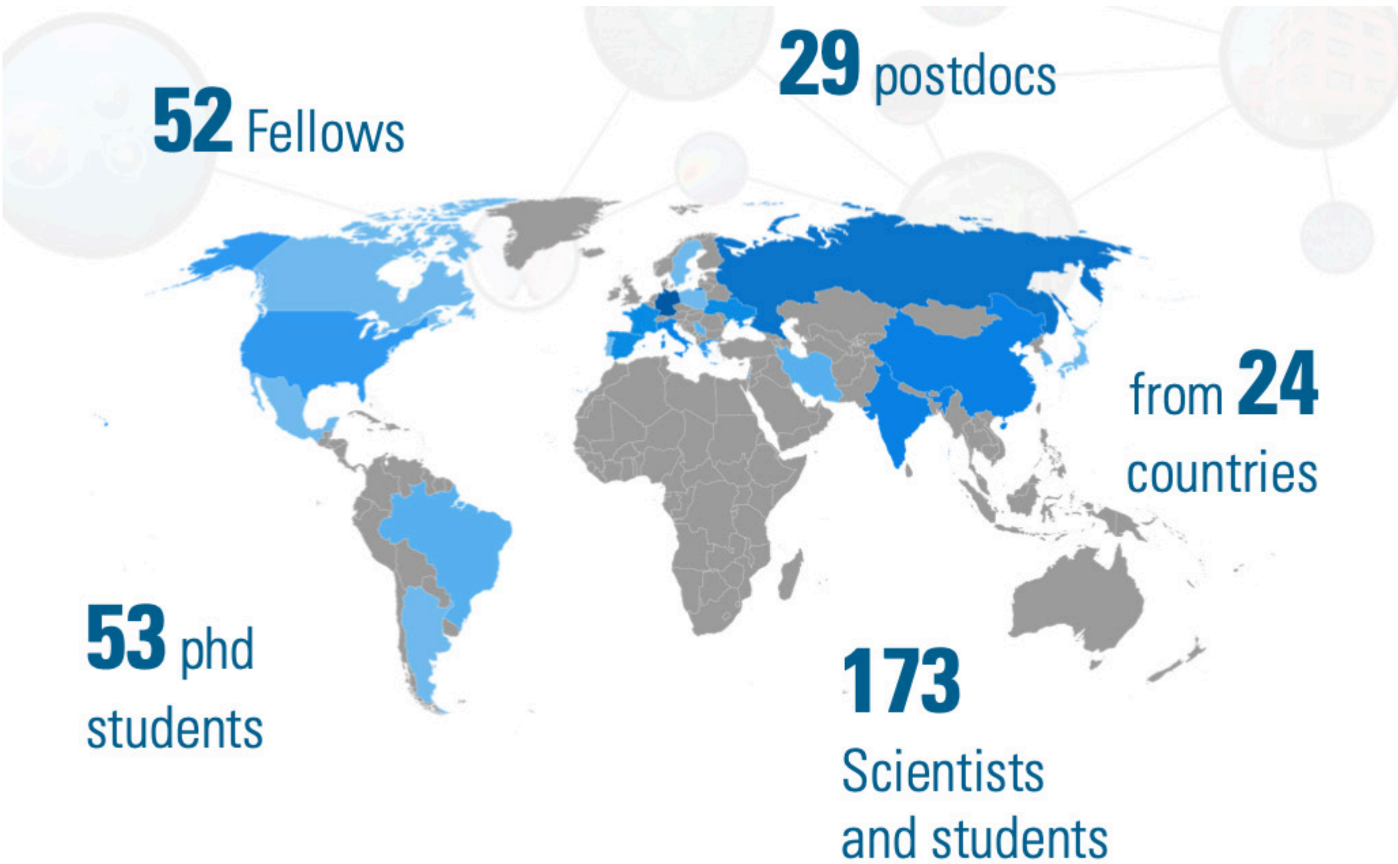
Top-level research in Frankfurt explained easily

Under this motto, a public lecture series was held in the fall of 2019 in cooperation with the Stiftung Polytechnische Gesellschaft.

FIAS Fellows presented their research in an understandable and entertaining way on four evenings. The topics were:

- Gravitational waves, neutron stars and hot quark matter in the laboratory
- Computing - Modeling and understanding complex systems
- In the realm of bacteria - memory without brain and communication without language
- Secret Brain

People at FIAS



The performance of any scientific institute depends crucially on the people involved with it. This is not different at FIAS – with their enthusiasm and engagement our researchers are the foundation of our success.

With 35% of our researchers being not from Germany, FIAS is very international. In 2019, we had scientist from 24 different nations working at our institute.

Many scientists are in Frankfurt only for a short time: PhD students stay for 3-4 years, and post-doctoral researchers mostly stay for 1-2 years. In addition we have about 10 guest researchers monthly, they visit FIAS for just a week or up to several months. This means we have new people coming to FIAS on a monthly basis and we are doing our best making them feel at home as soon as possible.

Behind all this stands a small, but strong administrative team, organizing everything in the background.

In memory of Stefan Schramm

This year we would like to take some time and remember Stefan Schramm, a friend, colleague and teacher who passed away in early 2019. By all who knew him, he will be long remembered. During his long and successful career in science, Stefan has guided and supported many students, young researchers and fellows in his well known calm and profound manner. To his students and collaborators Stefan was known as a source of extensive knowledge on physics as well as computational proficiency. Many remember being stuck and frustrated with a difficult problem, may it be physics or computing related, which Stefan seemed to solve effortlessly if not to just satisfy his curiosity.

In his career he has pioneered many projects. In the field of high energy nuclear physics he was instrumental in the development of the Frankfurt Chiral Mean Field Model which is now considered state-of-the-art in the international community. In addition to that he was always interested in broadening his horizon by making important contributions to the microscopic transport description and fluid dynamical description of dense nuclear matter. And this included not only the introduction of new physical phenomena. Stefan was one of the first to see and utilize the capabilities of modern computing infrastructures (e.g. use of GPU for scientific computing). Thus, he was one of the first directors of the Center for Scientific Computing in Frankfurt. In recent years he also recognized the importance of the emerging field of Machine Learning in fundamental sciences and was a strong supporter of the new group at FIAS aimed at AI for Science.
Stefan also pioneered research on the energy transition in Europe. He built up a group focusing on this research topic and set the basis for research on sustainable energy systems at FIAS. His contributions to this field were numerous and internationally recognized. Contributing to a sustainable future by addressing research problems and supporting open science to tackle climate change was one of his personal concerns and his passion for the topic inspired numerous people to follow his path.
At the same time he always was striving to transfer his scientific results to his private interests (and vice versa). A good example of this is a 'Bird-Sound' App that Stefan developed just before his passing, based on research done in FIAS.

We, the students, collaborators and colleagues of our dearly missed friend and mentor Stefan Schramm proposed to establish an award in his honor. A small sum has already been privately collected and we sincerely hope that FIAS, the Walter Greiner Gesellschaft as well as other generous friends of Stefan and FIAS will both contribute to the award and provide support in the next years.

Prof. Dr. Stefan Schramm has been a Fellow at our institute since the founding of FIAS in 2004.

Prof. Dr.
Nils Bertschinger

Nils Bertschinger is Helmut O. Maucher-Stiftungsjuniorprofessor for systemic risk. He studied computer science at RWTH Aachen and received his PhD from the Max-Planck Institute for Mathematics in the Sciences about information processing in complex systems. At FIAS he now applies methods from information theory and machine learning to investigate how systemic risks can develop and spread in financial systems.

Systemic Risk Stiftungsprofessur

In 2014, Helmut O. Maucher made the new Systemic Risk research area possible through his endowment.

Projects @ FIAS: 2

Collaborations

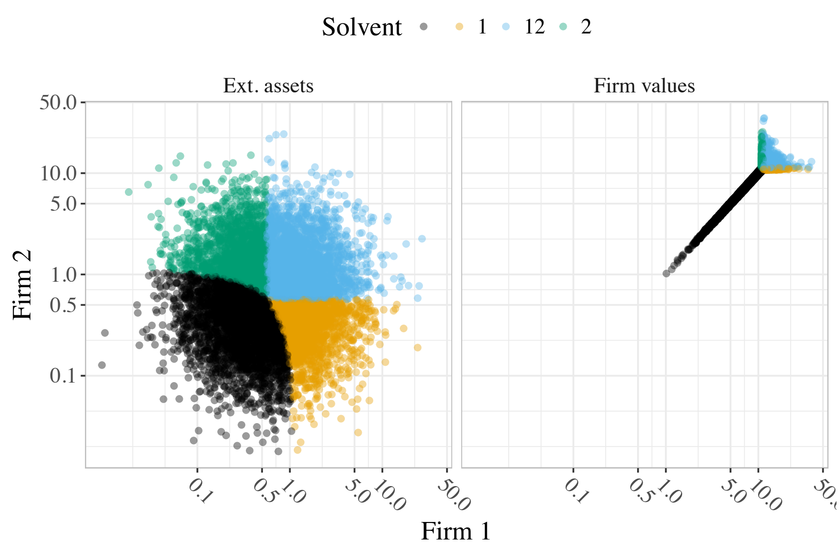
Juergen Jost, MPI for Mathematics in the Sciences
David Wolpert, Santa Fe Institute
Martin Hoefer, Goethe University

Systemic Risk

Structural risk modeling and management -- as introduced by Merton -- provides an ingenious link between firm risk and derivative pricing. Yet, current industry practice is focused on individual firms, ignoring financial cross-holdings. At the same time, financial innovation is increasing the interconnectedness and complexity of the financial network. Thereby, seemingly small risks can be substantially amplified and spread throughout the global financial network as painfully revealed during the latest crisis.

At FIAS, we are developing novel models for managing and pricing systemic risk, which take such network effects into account. In particular, we not only showed how, but also to which extend financial risks are amplified due to financial cross-holdings, as compared to the single firm case. To this end, we computed the so called Greeks -- standard measures of risk sensitivity -- in the network context. Furthermore, our model implies an explanation for why stock correlations rise in crisis time. Thereby, and for the first time, providing a solid theoretical understanding of this well-known statistical phenomenon. Currently, we explore further implications for systemic risk insurance: What is its fair value? How does its price change in different market conditions? Who should pay for the risk introduced by each financial contract?

While this important project is still at an early stage, it will be substantially expanded. Indeed, our investigations of financial networks form the basis for a sub project in the DFG Forschungsgruppe "Algorithms, Dynamics, and Information Flow in Networks" that has just been granted. Together with Prof. Hoefer, who leads the Forschungsgruppe, and other colleagues from theoretical and applied computer science, we are now seeking innovative models to understand and model dynamics of and on networks. In terms of applications, we will address fundamental and pressing questions regarding finance, epidemics and online marketing.

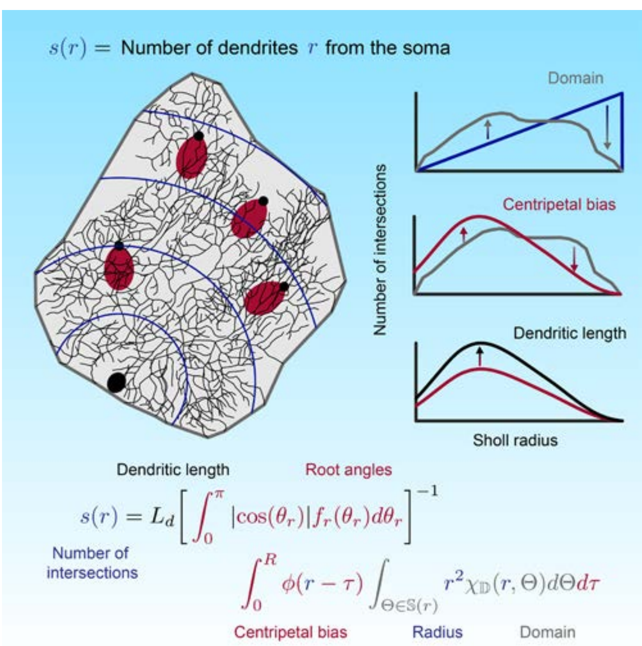


Possible future scenarios for actual business assets (left) and total values (right) of two firms with cross-holdings of debt. Note that firm values are substantially increased and strongly correlated due to cross-holdings.

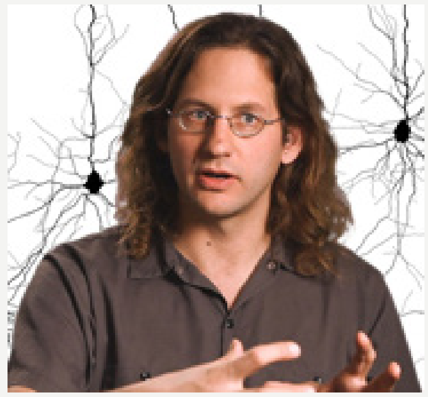
Sholl analysis

Sholl analysis provides a simple one-dimensional representation of a neuron's structure. It is obtained by centring spheres of increasing radius around the cell body of a given neuron while counting the number of intersections between the spheres and the dendritic tree. Sholl analysis is widely used to evaluate the effects of pathologies, genetic manipulations, and treatments. Despite this broad usage, the factors that lead to a given Sholl representation have not been consistently described until now. In our recent work published in Cell Reports (Bird and Cuntz, 2019) we find that the results of Sholl analysis can be accurately predicted by just three key features of a neuron's dendrite: the spanning domain in which it can receive synaptic contacts, the total length, and the angular distribution of how far dendritic branches deviate from a direct path to the soma. The last of these is described by a new metric, the root angle distribution, which has implications well beyond this study. Each of the three factors has an interpretation relating to neuronal connectivity or metabolic efficiency, allowing the changing functionality of a neuron to be described from its Sholl representation.

The results of this study are particularly interesting as they complement our method to generate synthetic dendrite morphologies from simple optimal wiring constraints (Cuntz et al, 2010 PLoS CB). In that work we show that the full details of dendrite morphology can be modelled faithfully based on the assumption that dendrites minimise two costs: total dendrite length and conduction times from synapses to the dendrite root. The two costs are weighted with the one parameter in the model. Interestingly, the root angle distribution derived in the current work allows to precisely infer this parameter making our morphological models essentially parameter-free.



Sholl analysis, a one-dimensional representation of a dendritic tree, can be reproduced from three basic properties of a neuron that define its connectivity, density of synaptic inputs, and balance between material and signal delay costs, thus linking an intuitive and accessible neuronal representation with function. From Bird and Cuntz, Cell Reports, 2019, 7(10):3081-3096.e5.



Dr. Hermann Cuntz

In the year 2013 he received the prestigious Bernstein Award with a prize money of around 1.25 million Euros to establish a group at FIAS and the Ernst Strüngmann Institute. He is approaching cellular neuroanatomy in a similar comparative manner as Santiago Ramón y Cajal one of the founders of the field of Neuroscience. Instead of using pen and paper as in his beautiful drawings Hermann Cuntz now takes advantage of computer models to reproduce dendritic structures from simple general principles.

Science at Centre Pompidou

His groups virtual reality (written by Marvin Weigand) has made it to the Centre Pompidou for an exhibition.

Projects @ FIAS: 1

Collaborations

Peter Jedlicka
Gaia Tavosanis
Stephan Schwarzacher
Thomas Deller

Prof. Dr.
Hannah Elfner

Hannah Elfner is leading a Helmholtz Young Investigator Group at FIAS since October 2012.
She obtained her PhD degree at Goethe University in 2009 sponsored by a stipend of the Deutsche Telekom Stiftung and spent 3 years as a Humboldt fellow and visiting assistant professor at Duke University.
Her work concentrates on the dynamical description of heavy ion collisions with transport and hydrodynamics.

Heinz Maier-Leibnitz
In 2016, she received the most prestigious award for young scientists in Germany by the DFG and BMBF.

Projects @ FIAS: 2

Collaborations

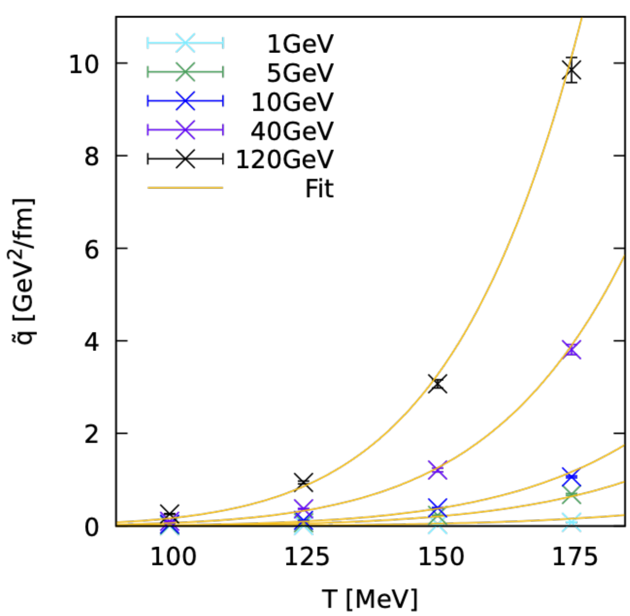
Dunja Bruder (HZI), Veronika von Messling (PEI), Franklin Toapanta (Maryland University), Yassine Taoufik (Hôpital Bicêtre), Frank Pessler (MHH)

Transport coefficients in the hadronic medium

Investigating the properties of hot and dense nuclear matter in terms of transport coefficients is one of the major goals of heavy-ion physics. To gain a quantitative understanding of the transport coefficients of the quark-gluon plasma and their temperature and density dependence, it is crucial to evaluate the properties of a hadron gas at different values of temperature and chemical potential. This task has been tackled over the last years within the transport approach SMASH (Simulating Many Accelerated Strongly-interacting Hadrons). The shear viscosity has been most extensively studied and found to be very sensitive to the lifetime of the resonances, which delay the relaxation dynamics once the mean free time becomes of the same order of magnitude. This finding explains the discrepancy between previous results in the literature. The bulk viscosity is very sensitive to inelastic processes and by neglecting the slowest modes an effective bulk viscosity has been determined that is constant as function of temperature within error bars and not rising as previous calculations suggested.

The electric conductivity is not very sensitive on resonance properties, since the charge diffusion dynamics does not depend on the lifetime, since the charge transfer already happens at the formation of a resonance. In addition, the so called cross-conductivities have been studied for the first time. They represent the cross-talk between different conserved charges like electric charge, baryon number and strangeness. By analyzing those for different mixtures of hadrons, a clear dependence on the active degrees of freedom has been determined that can be valuable in future comparisons to lattice QCD calculations. In 2019, one publication on the transport coefficient relevant for energy loss has been published.

This work was done as part of the PhD thesis by Jean-Bernard Rose. Mr. Rose has served as a student representative at FIAS from 2016-2018 and obtained a Giersch Excellence Award in 2017.

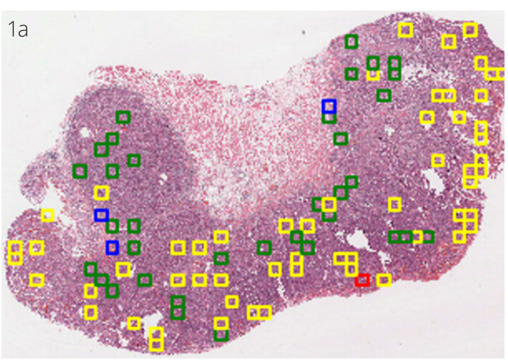


The energy loss per unit lengths of pions in a hadronic medium at different energies and for different temperatures.

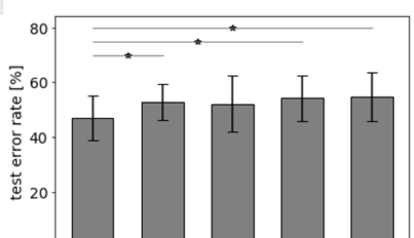
Systems Medicine of Infectious Diseases

In 2019 I started a new collaboration with the pathology department of the university hospital Frankfurt (Prof. Dr. P. Wild) where we try to predict the molecular subtype of gastric cancer based on the morphology present in H&E stained tissue slices, which are routinely generated for all patients. These molecular subtypes are EBV, MSI, GS and CIN and are defined based on clustering of e.g. mRNA and protein expression data and methylation profiles[1]. Convolutional neuronal networks (cNN's) are used to predict the predefined molecular subclass based on the observed morphology. Using only a certain subset of the patients deposited in the TCGA database, a high accuracy/ low error rate (~90%/~10%) can be achieved. On the one hand these networks can be used to investigate the intra-tumor heterogeneity and to investigate if a certain patient is positive for several subclasses (Figure 1A). On the other hand a more detailed investigation of these trained networks using Grad-CAM (Gradient-weighted Class Activation Mapping)[2] unravel which parts of the pictures and hence which morphological features are important for the prediction and classification into the special subtype. For example in pictures classified as EBV, areas with small lymphocytes are important and the GS class is related to connective tissue. The use of 20 randomly picked patients however results in worse error rates (~50%), which is still better than guessing (error rate: 75%) and improves with the number of patient used for training. However EBV correspond to only ~10% of the data and strong oversampling of this subclass to enable the use of more data for the other subtypes does not significantly decrease the error rate (Figure 1B).

1. Cancer Genome Atlas Research Network. Comprehensive molecular characterization of gastric adenocarcinoma (2014) Nature. 513(7517):202-9.
2. Selvaraju RR, Cogswell M, Das A, Vedantam R, Parikh D, Batra D. Grad-CAM: Visual Explanations from Deep Networks via Gradient-based Localization (2016) IEEE Computer Vision and Pattern Recognition (CVPR)



1b



CIN slides	20	20	20	20	5
EBV slides	20	5	5	5	5
GS slides	20	20	5	5	5
MSI slides	20	20	20	5	5
pic/class	300	300	300	300	300

Dr. Nadine Flinner

Nadine Flinner studied bioinformatics and worked on the structure and phylogeny of membrane proteins during the diploma thesis. In her PhD, finished in 2015, she investigated the behaviour of membrane proteins using molecular dynamic simulations.
Nadine Flinner started her PostDoc at FIAS investigating the migration of immune cells and is now interested in understanding the correlation between cell morphology and the underlaying molecular features.

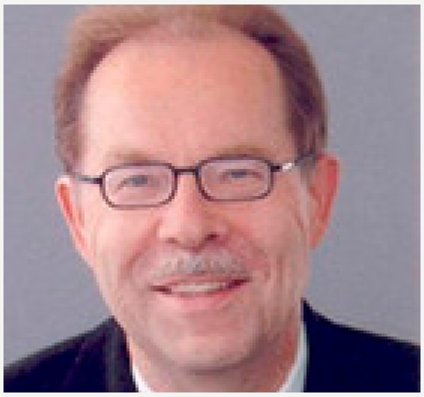
New Research Fellow

Nadine Flinner became a group leader and FIAS Research Fellow in 2019.

Collaborations

Peter Wild, Goethe University

Olga Goncharova, Dr. Senckenberg Institute of Pathology



Prof. Dr.
Martin-Leo Hansmann

Martin-Leo Hansmann studied medicine and biology in Bonn. After recieving his diploma in 1974 and his medical state examination in 1977, he received his doctorate in 1982 and habilitated in 1987. From 1990 to 1996 he was Professor at the Institute of Pathology at the University of Cologne and since 1996 Professor at the Senckenberg Institute of Pathology at the Goethe University.
Hansmann joined FIAS in 2016 his main expertise lies in haematopathology, the molecular pathology of malignant lymphomas.

Highlight

In 2001 he was awarded the German Cancer Aid Prize.

Projects @ FIAS: 1

Collaborations

Dr. Wojciech Samek (Frauenhofer HHI), Prof. Dr. Frederick Klauschen (Charite' Berlin), Prof. Dr. Klaus-Robert Müller (TU Berlin)

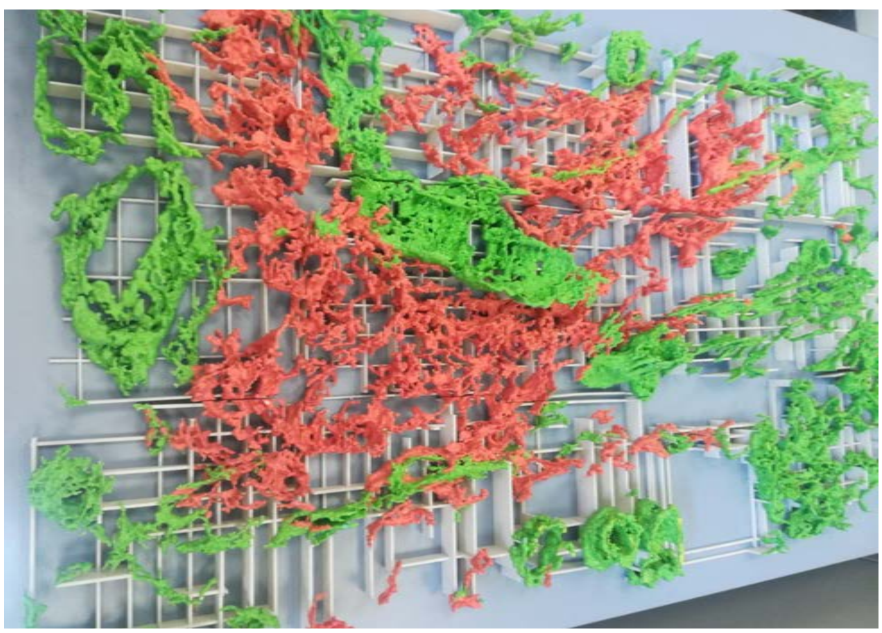
Computational life science on deep learning Biomedicinie

The immune system tries to protect us, as humans have to defend themselves, all the time against infections like bacteria, viruses and tumour cells. The scientific project presented here focuses on lymph nodes and their strategies to detect and to eliminate dangerous agents. Lymph nodes clean the lymphoid fluid in our body using different cell types like B-,-T cells, macrophages, antigen-presenting cells distributed in different compartments.

Our group applies laser scanning technologies to visualize the lymph-node system in 2D and 3D. In addition we have established a technology that enables to describe human immuno reactions in tissues in movement. Using bioinformatics and deep learning tools, we are able to describe and probably forecast immuno reactions by determining homoeostatic factors in immune defence. Volumes as well as surface areas, amounts and duration times of cell contacts can be determined. In addition, movement signatures and movement hotspots can be described.

These findings are new and informative and give more insights in amounts, qualities and properties of different immune cells and the molecular subsets. In the future such data may be routinely provided to conventional histology and immuno histochemistry to improve diagnostics and to establish individual diagnosis and therapy.

Using such methods therapeutic strategies may be more exactly calculated and the strength of the human immune system of an individual patient may be determined.



Visulized lymph-nodes

A new perspective on dark matter

I started out as a particle physicist and then worked in quantum gravity for a decade. But a few years ago my interest wandered towards astrophysics, and its connection to both particle physics and quantum gravity. In 2019, I am happy to report, I secured my first research funding to work on an astrophysical project. Together with PhD candidate Tobias Mistele and collaborator Stacy McGaugh in Ohio, USA, we are exploring the possibility that dark matter may form a superfluid.

What makes up dark matter is one of the most pressing problems in the foundations of physics today. It has remained unsolved for more than 80 years. The problem is that we cannot explain what we observe in the cosmos using Einstein's theory of General Relativity and assuming the universe is populated only by the matter we know. It just doesn't work. We either need to postulate a new type of matter – "dark matter" – to fix the mismatch between theory and observation, or we have to consider that General Relativity does not work the way that Einstein taught us. The latter option has gone down in the scientific literature as "modified gravity".

The in my eyes most exciting development in this field has been the realization that the best explanation for the data may be a combination of both, dark matter and modified gravity. Certain types of superfluids can sometimes act as dark matter and sometimes mimic a modification of gravity. Coincidentally, a simple model that I worked on some years ago has this property. In the coming years I want to study in more detail what predictions this model makes, how well they fit to existing observations, and what new observations could be useful to tell this model apart from normal dark matter.

Dr.
Sabine Hossenfelder

Sabine graduated from Frankfurt in 2003 and was a postdoctoral fellow, among others, at UC Santa Barbara, and the Perimeter Institute in Canada. Before returning to Frankfurt, she held a position as assistant professor at Nordita, in Stockholm, Sweden. Sabine's research is presently supported by the Swedish Research Council, the German Research Foundation, and the Foundational Questions Institute. Besides her research, Sabine is also active in science communication.

Science Communicator

Sabine writes for several magazines, hosts a popular science blog and published her first book in 2019.

Projects @ FIAS: 4

Collaborations

Nordita, Stockholm
Perimeter Institute, Canada
SISSA, Trieste

NGC 1672: Barred Spiral Galaxy from Hubble
Image Credit: Hubble Legacy Archive, NASA, ESA; Processing & Copyright: Domingo Pestana & Raul Villaverde

**Prof. Dr.
Matthias Kaschube**

Matthias Kaschube studied Physics and Philosophy in Frankfurt and Göttingen and obtained his doctoral degree in theoretical physics working with Fred Wolf and Theo Geisel at the Max Planck Institute for Dynamics and Self-Organization. From 2006-2011 he was Lewis-Sigler Theory Fellow at Princeton University, working on theoretical neuroscience and developmental biology. In 2011 he joined FIAS and became Professor for Computational Neuroscience at Goethe University.

Vice-Dean

From 2017-2019 he served as Vice-Dean of the Goethe Universitys Department of Informatics and Mathematics.

Projects @ FIAS: 10

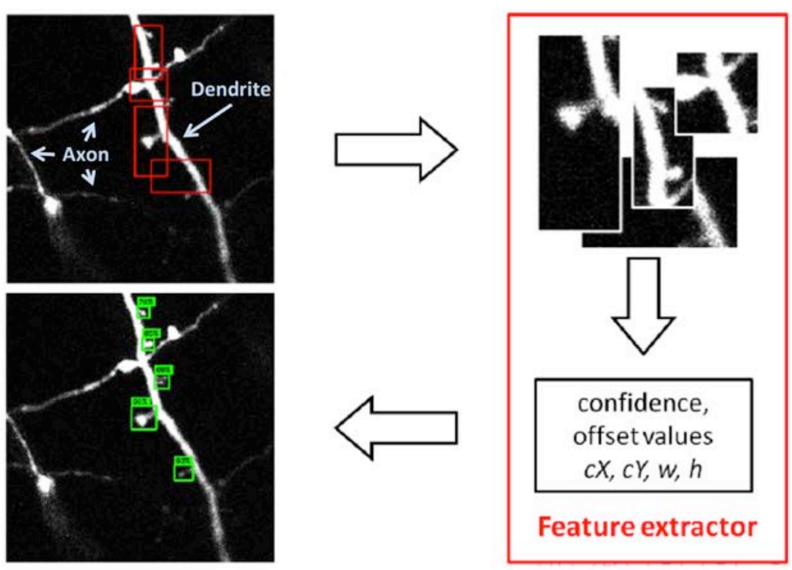
Collaborations

David Fitzpatrick (Max Planck Florida Institute), Simon Rumpel (Univ. Mainz), Gilles Laurent (Max Planck Institute for Brain Research), Kenichi Ohki (Univ. of Tokyo)

Deep learning-based detection of synaptic connections

The functionality of neural circuits in the brain depends significantly on the strengths of synaptic connections between neurons. Recent developments of deep tissue live imaging techniques enable to visualize large numbers of synapses and to monitor them over extended periods of time, from hours up to several weeks. Extracting the strengths of synaptic connections and analysing how they change across time, for instance while an animal acquires the skills necessary to perform a given task, could shed important light on the neural underpinnings of learning. However, measuring the strengths of individual synaptic connections from live imaging data has been a daunting task relying largely on visual inspection and manual annotation and so difficulties in scaling this up to simultaneous measurements of large numbers of synapses has been the bottleneck in such analyses. In collaboration with neurobiologist Simon Rumpel at the University of Mainz, we have made significant improvements towards developing a scalable image analysis pipeline, enabling to automatically detect large numbers of spines (proxies for synapses) in fluorescence imaging stacks and to track them across several days (Figure; Vogel et al., manuscript in preparation). For spine detection we exploited transfer learning, adopting a deep convolutional neural network (CNN) that was pretrained to detect and classify objects in natural images. We combined a Faster R-CNN to generate and refine region proposals of candidate spines with an Inception-ResNet for the recognition step of spines. The detection outperforms previous methods and achieves a near human level performance (F1 score of 0.90 tested on data sets labeled by n=5 experts; for experts, F1=0.94).

The work arose from an excellent bachelor thesis by Fabian Vogel, previously recognized as Hessen's youngest student entering the computer science program at Goethe-University at the age of 16.



Deep learning-based detection of synaptic connections (so-called spines are used as a proxy for synaptic connections): First, using pre-trained convolutional neural networks a large number of candidate regions (proposals of spine locations) are automatically generated (red boxes; only a small subset is shown). Then, each region is evaluated for the presence of a spine and refined in size and position (green boxes). For illustration, only a small dendritic branch is shown. The method can reliably distinguish dendritic spines from axonal structures

Block chain technologies in public administrations

The cooperation between the Hessische Zentrale für Datenverarbeitung (HZD) and the FIAS was started with a doctoral research project. The goal of the collaboration is to research block chain technologies in public administrations.

Since blockchain technology is still very young, its application potential must be investigated and tested for security. Promising features of this technology, such as decentralization, transparency and immutability, offer many possibilities, especially in relation to digital identities. These identities will not be limited to persons, but can also form objects, files or similar.

In the doctoral thesis, an interface of a block chain identity solution to the Radius protocol will be built. Radius is a protocol used for dial-up connection to a computer network. Authentication, authorization and accounting (AAA) are realized.

This protocol is used for the eduroam network among others. This enables students to dial into the W-Lan infrastructure by registering at one university at other universities participating in the eduroam network. The participating universities exchange the necessary information with each other.

Combined with the blockchain identity, we expect a resolution of hierarchical PKI structure in the Radius protocol with the potential to be faster and safer to implement. This will be the subject of a doctoral thesis.

In addition, the solution will be integrated into an existing framework of the HZD, thus enabling adoption into the corporate network.

Prof Dr.
Udo Kebschull

Professor Udo Kebschull studied computer science at the Technical University of Karlsruhe (today KIT) and graduated in 1989. From 1989 to 1990 he worked as a scientific employee at the FZI in Karlsruhe. After working in Leipzig and Heidelberg, in 2010 Udo Kebschull became head of the University Computer Center of the Goethe University Frankfurt in connection with a chair for infrastructures and computer systems in information processing.

New FIAS Fellow

His research focuses on the low-latency processing of large amounts of data, such as those generated by experiments in high-energy physics

Projects @ FIAS: 1

Collaborations

Hessische Zentrale für Datenverarbeitung (Hessian center for data processing)

Prof. Dr.
Ivan Kisel

Ivan Kisel works on data reconstruction in high-energy and heavy-ion experiments. His approach based on cellular automata allows to develop parallel algorithms for real-time physics analysis using HPC. He received his PhD in physics and mathematics from the Joint Institute for Nuclear Research (Dubna, 1994). Then he worked at the University of Heidelberg, where he gained his habilitation in physics, in 2009, and at the GSI Helmholtz Centre for Heavy Ion Research. Since 2012, he is a professor for software for HPC at the Goethe University and a fellow at FIAS.

Featuerd Project

You will find more about his work in the featured article on page 13 within this issue.

Projects @ FIAS: 2

Collaborations

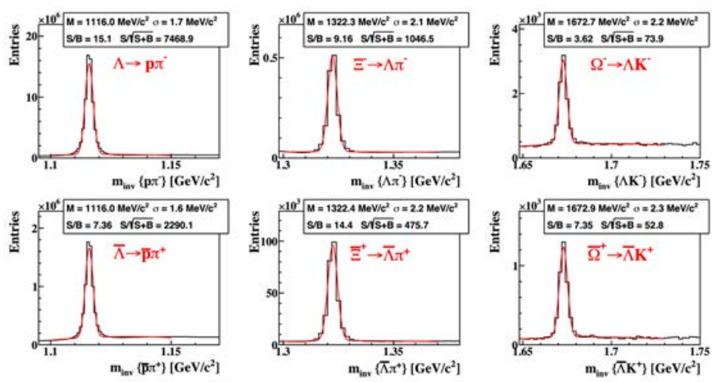
CBM
PANDA
ALICE
STAR

Algorithms for heavy ion collisions

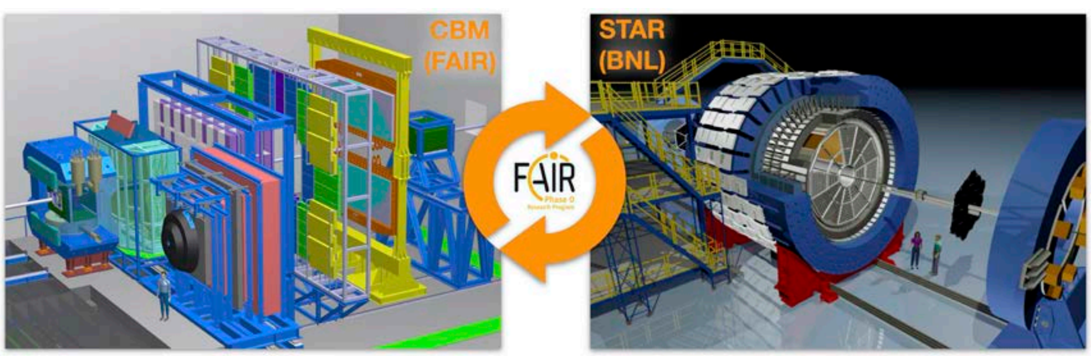
In 2019 the work of Prof. Dr. Ivan Kisel's group was focused on further development of the algorithms for processing and analysis of heavy ion collisions, which are part of FLES (First Level Event Selection) package of the CBM experiment (FAIR/GSI). The goal of FLES is to provide full data analysis in the CBM experiment in real time at 10^7 heavy ion collisions per second.

At this stage the work was carried out to investigate and improve the accuracy of the algorithms, as well as their reliability in the conditions of working with real data in online mode. For this purpose, we used the data of the experiment STAR (BNL, USA), which is now collecting data in the program BES-II (Beam Energy Scan) on the accelerator RHIC at collision energies close to the energy of the CBM experiment.

The work was carried out within the framework of the FAIR Phase-0 program, which is to participate CBM scientific teams in other experiments in order to test and improve the detector systems and algorithms developed for CBM under real conditions of other experiments already in operation. In this case, the use of such detector systems and processing algorithms is expected to significantly accelerate the start of the CBM experiment itself in the future.



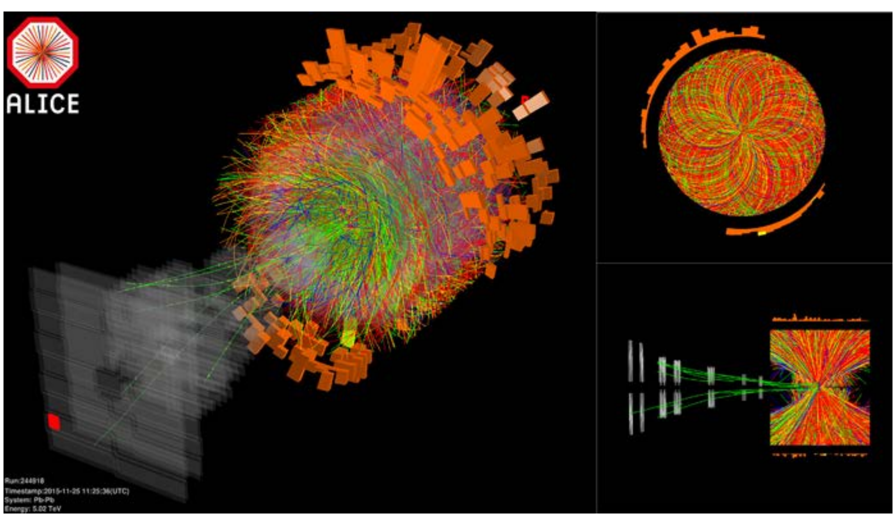
STAR xHyperons:
short lived particles reconstructed online in the STAR experiment in 2019 using the algorithms of the CBM experimen



Schematical presentation of the FAIR Phase-0 program

ALICE at CERN

The ALICE Experiment at CERN concentrates at the measurement of heavy ion collisions at ultra high energies. During the collision a matter state is created, which also existed during the first microseconds after the Big Bang. Many properties of matter can be studied that way. ALICE was designed to measure all charged particles emerging from such collisions. After a very successful measurement campaign ALICE is now in a shut down phase where the detectors are upgraded to handle more than 50 times the original collision rate. This involves in part a complete redesign of the detectors. As a consequence the data rate is increasing accordingly. A further complication of the system is that the data, which emerges from the experiment at a rate exceeding 3 TeraByte/sec has to be analyzed on-line for selection of the most relevant data. The data is transferred with more than 9000 optical links, which end in 475 PCIe cards mounted in general PCs. The analysis will be performed by a high performance computer implementing 16000 processor cores and 2000 GPUs. Since the data belonging to one interaction is shipped in parallel to those 475 PCIe cards, those data fragments have to be assembled in one target computer taking into account that not all processing requires the same amount of time. An appropriate scheduling algorithm has been developed which can handle such high data streams and still manage the data assembly. A complete prototype including prototype hardware was designed and is now in operation at various detector test setups. It's performance and reliability was already demonstrated. Appropriate servers were evaluated and the acquisition of the system is currently being prepared. ALICE was the first experiment ever that has used FPGAs, GPUs and CPUs together for the on-line data analysis. This work has become a role model for the new experiment setups. In order to understand the complexity of the analysis the image shows one of the first heavy ion collision events measured at ALICE as seen from different perspectives. The algorithm uses the measured hits in the detectors and combines them to the tracks as shown in the image. It should be noted that the new ALICE setup will produce about 50000 of those collisions and corresponding images per second. This complexity has to be handled by the computer farm, currently being built.



Reconstruction of a Pb-Pb collision at 5,02 TeV.

Prof. Dr.
Volker Lindenstruth

Professor Volker Lindenstruth studied physics at TU Darmstadt and received his doctorate in 1993 at Goethe University. He spent his Postgraduate years at the UC Space Science Laboratory. In 1998, he returned to Germany as a Professor and department head at the University of Heidelberg. In addition, he has been the head of the ALICE HLT project at the LHC since 2000. In 2007 he joined Goethe University as professor and at FIAS he held the position of Fellow but became a Senior Fellow soon thereafter.

Patentet Technology

The energy-saving high-performance data centers he co-developed were successfully patented.

Projects @ FIAS: 4

Collaborations

CBM
ALICE

**Prof. Dr.
Franziska Matthäus**

Following her studies in biophysics at the Humboldt University of Berlin, including one year research stay at UC Berkeley (USA), Franziska Matthäus spent five years in Warsaw (Poland) on her PhD and scientific research. Between 2005 and 2016, she held two postdoc positions and a group leader position at IWR, University of Heidelberg. In 2016, she received a junior professorship at CCTB, University of Würzburg. Since October 2016, she holds a W2 position in bioinformatics, funded by the Giersch-Foundation.

The Art of Theoretical Biology

For the book published by Springerverlag she collected pictures from all areas of theoretical biology.

Projects @ FIAS: 1

Collaborations

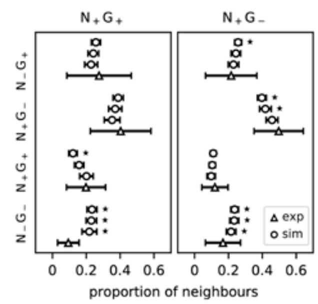
A. Frangakis, E. Stelzer, (GU), D. Headon (Roslin Inst. Edinburgh), K. Breuhahn (Univ. Hospital Heidelberg), U. Klingmüller, DKFZ Heidelberg, M. Engstler, (Univ. Würzburg)

Modeling Multicellular Systems

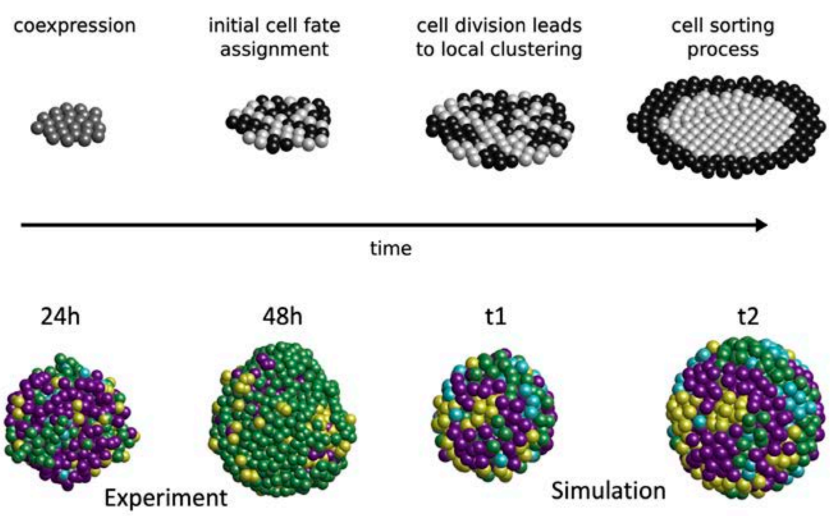
During the mammalian preimplantation phase, cells undergo two subsequent cell fate decisions. During the first decision, the trophectoderm and the inner cell mass are formed. Subsequently, the inner cell mass segregates into the epiblast and the primitive endoderm.

An experimental model system, mimicking the second cell fate decision taking place in in vivo mouse embryos, are the so-called inner cell mass organoids. These ICM organoids are spherical multicellular systems which reproduce the second cell fate decision, and can be studied by fluorescence microscopy using different markers for the different cell fates. In these experimental systems it has been shown that cells of the same fate tend to cluster stronger than expected for random cell fate decisions.

Three major processes are hypothesised to contribute to the cell fate arrangements at the mid and late blastocysts or 24 h old and 48 h old ICM organoids, respectively: 1) chemical signalling, 2) a cell sorting, and 3) cell proliferation. In order to quantify the influence of cell proliferation on the observed cell lineage type clustering, we developed a mechanical agent-based model, accounting for mechanical cell-cell interaction, i.e. adhesion and repulsion, cell division, stochastic cell fate decision and cell fate heredity. The model supports the hypothesis that initial cell fate acquisition is a stochastically driven process, taking place in the early development of inner cell mass organoids. Further, we show that the observed neighbourhood structures can emerge solely due to cell fate heredity during cell division.



Comparison of neighborhood statistics between experiment (triangles) and simulation (circles). Simulated data were generated for three different time points of cell fate acquisition. The first (lowest) time point refers to a cell fate decision when the organoid is assembled and agrees best with the experimental data.



Hypothesis outline: Cell fate clustering occurs due to cell division and cell fate heredity and represents an intermediate phase between cell fate acquisition and cell sorting. Bottom left: cell fate distribution in organoids in experiment and simulation.

Equation of state for osmological matter at and beyond QCD and electroweak eras

Various thermodynamic quantities of baryon-free cosmological matter are obtained by combining the most reliable non-perturbative and perturbative calculations. Especially, we use the most recent lattice computations including as many quark flavors as possible. These results are extended by including other degrees of freedom (dof), such as photons, neutrinos, leptons, electroweak particles and Higgs bosons, that allows us to consider temperatures up to the TeV-scale. We have found that while the equation of state for the hadronic matter is rather simple, p~\rho, the one for higher temperatures is more complex, exhibiting two crossover-type phase transitions, corresponding to strong and EW matter. At even larger energy densities, the deduced EoS becomes linear again and close to ideal gas. Analytical parameterizations of combined data are obtained.

A second project has dealt with possible Bose-Einstein condensation of alpha-particles in ground tate of nuclear matter. We study the role of alpha-like correlations in the symmetric nuclear matter around its saturation density. The phase diagram of isospin-symmetric chemically equilibrated mixture of α-particles and nucleons (N) is calculated within the mean-field approximation with Skyrme-like interaction potentials. Their parameters are chosen in such a way that the properties of the pure nucleonic and pure α-matter are reproduced correctly. We find that the properties of the mixed α-N matter depend essentially on the model parameter a (Fig. 2), controlling the attractive interaction between α particles and nucleons.

Prof. Dr.
Igor Mishustin

Igor Mishustin studied theoretical physics and astrophysics at the Moscow State University. He obtained his PhD and then the Doctor of Sciences degree (habilitation) at the Kurchatov Institute in Moscow. After long-term stays in the Niels Bohr Institute (Denmark) and the University of Minnesota (USA), he joined the newly-established Frankfurt Institute for Advanced Studies, in 2004. Here he leads the group of theoretical subatomic physics and astrophysics.

Medicine Physics

In addition to his work in subatomic and astrophysics, he has done important research on cancer therapy with ion beams.

Projects @ FIAS: 1

Collaborations

Abdel Nazer Twfik

L.M. Satarov

M.I. Gorenstein

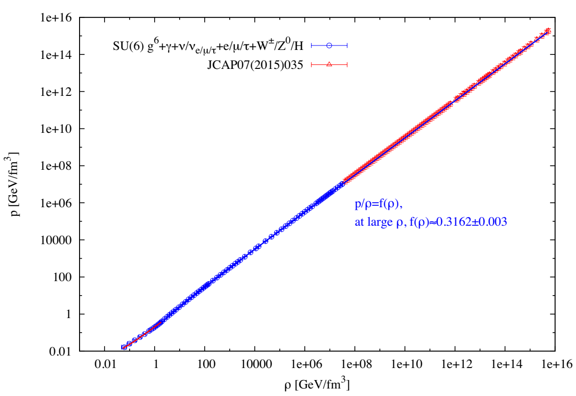


Fig. 1: The resulting equation of state, which covers over 20 orders of magnitude in the energy density. These results can be used for modelling the expansion of the Universe from very early times and through the EW and QCD era.

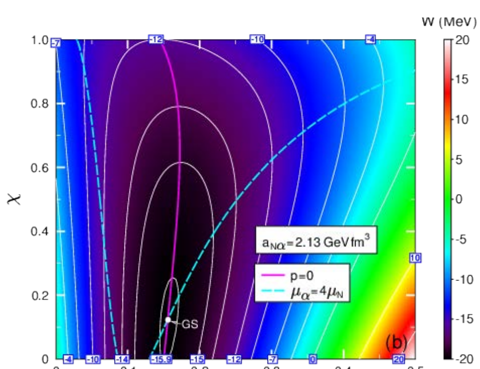


Fig. 2: At a<a* the ground state of nuclear matter at zero temperature consists only of interacting nucleons, whereas at a>a* it includes also an admixture of α-particles, see Fig.2. It is demonstrated that the equation of state of such α-N system contains both the first-order liquid-gas phase transition and the Bose-Einstein condensation of α particles. We have calculated the phase diagram of such a mixture in a broad range of baryon densities and moderate temperatures.

Prof. Dr.
Piero Nicolini

Piero Nicolini received his PhD from the University of Bologna in 2002 and his habilitation from the Goethe University in 2013. After postdoctoral positions in Marseille and in Trieste, he is currently a Research Fellow at FIAS and an Apl. Professor at the Goethe University. His research interests cover quantum gravity, quantum field theory, and theoretical particle physics. Prof. Dr. Piero Nicolini is best known for having first proposed noncommutative geometry as a tool for studying evaporating black holes beyond the semiclassical limit.

APL Professor at GU

Piero Nicolini was appointed as an extracurricular by the Department of Physics at Goethe-University.

Projects @ FIAS: 1

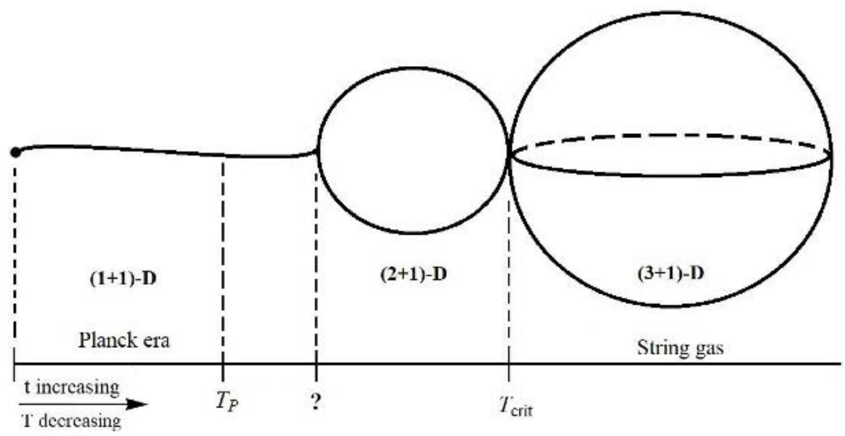
Collaborations

R. Casadio, Univ. Bologna
M. Kaminski, Univ. Alabama
Maximiliano Isi, Caltech
J. Mureika, LM Univ. Los Angeles
Prof. Dr. Roldao da Rocha, ABC Federal University, Dr. Anais Smailagic, INFN, Trieste, Dr. Euro Spallucci, Univ. Trieste

Classical and Quantum Gravity

The group activity has focused on the physics of the early Universe during the Planck era, an epoch characterized by exotic objects like strings, branes as well as evaporating black holes. Despite the difficulties related to a consistent quantum theory of gravity, the group has achieved three major breakthroughs in the field: 1) the determination of the production rate of black holes in an dimensionally reduced Universe; 2) the derivation of the first analytical solution of Einstein equations describing a gravitational monopole; 3) the derivation of the first analytical, singularity free, black hole solution by employing string T-duality modifications for the graviton propagator. Each of the above projects can be ranked as seminal ones due to their originality. We underline here the first one only, having been the subject of a PhD thesis graded with Summa cum Laude at the Goethe University.

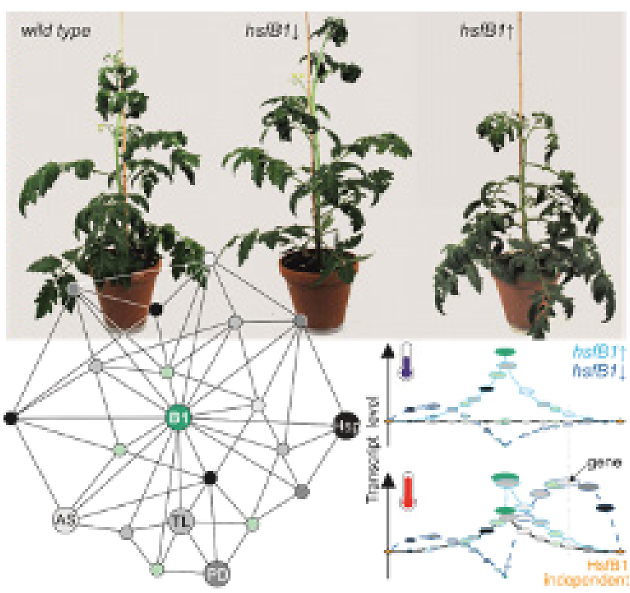
According to the original derivation by Mann-Ross and Hawking-Bousso, de Sitter space is quantum mechanically unstable, decaying into black hole pairs. Such black holes, however, would not significantly contribute to dark matter since they form prior the inflation, namely for a Planckian cosmological constant only. Against this background, we considered an effective dimensional reduction of the Universe according to the 't Hooft proposal. Due to the triviality of Einstein gravity, we employed a dilaton gravity action to evaluate the Euclidean Quantum Gravity path integral. Remarkably, the resulting production rate does not depend on a specific energy scale opening the route to the production of black holes even after the inflation. Our findings might help to solve the current issues on the nature of dark matter.



Dimensional reduction/oxidation of the Universe. The spacetime dimension evolves according to the energy scale at which the Universe is observed.

Heat Sweet Tomato

The cellular homeostasis and surveillance depends on fluxes of information, molecules, proteins and organelles. The understanding of the underlying molecular principles is fundamental for the description of the behavior of any organism and requires the combination of experimental and theoretical approaches. Our team focuses on the fundaments of the regulation of the life cycle of proteins and the signal transduction systems to maintain the homeostatic state under changing environmental conditions. We use plants as model organisms, because plant cells operate as eukaryotic cells where fundamental principles are globally conserved. In addition climate change in conjunction with the increase of the global population requires intensive plant research to ensure the production of food and renewable energy resources. One of the five fields approached in our laboratory concerns the plant reaction to altered environmental conditions like temperature fluctuations. In contrast to humans, plants withstand a large temperature range due to the existence of a complex regulatiry network. Central units are the Heat Shock Transcription Factors (Hsfs), which have been classified by bioinformatics means. Based on this classification, the central Hsfs were identified and their importance for plants explored. Combining whole plant analysis, large scale approaches (Omix) to describe the proteomic content and bioinformatics, we discovered that one of the central Hsfs annotated as HsfB1 fine tunes the response network to elevated temperatures. This result was in part expected as previous biochemical studies suggested an impact on the transcriptional activity of the so called master regulator HsfA1. More importantly, our study provided strong evidence for an impact of the transcription factor for normal development as well. Its repression results in an enhanced growth and its overexpression in a reduced growth under normal conditions. This information changes the view with respect to breeding strategies, because future strategies have to target dose variation of a certain factors, but no longer their absence or presence.



Prof. Dr.
Enrico Schleiff

Prof. Dr. Enrico Schleiff, studied physics at the Charles University in Prague, and later at the Gutenberg University in Mainz and at the University of Basel. In 1999 he did his PhD at McGill University Montreal, Canada. Later he worked at Christian-Albrechts-University zu Kiel and the LMU, Munich. Since 2007, he has held a W3 professorship for Molecular Cell Biology of Plants at the Institute of Molecular Biology at GU Frankfurt. In 2017 he joined FIAS as Senior fellow and became its chairman in 2018.

Chairman of the Board

Since 2017 he has been a member of the FIAS board of directors, which he currently also chairs.

Projects @ FIAS: 2

Collaborations

SPOT-ITN
DynaMem
SFB 807 / 902
Nir Keren,
Hebrew Univ. Jerusalem
Arndt von Haesler, CIBIV, Wien

The function of HsfB1 was explored by experimental approaches and bioinformatics means.

Dr. Armen Sedrakian

Dr. Armen Sedrakian received his physics degree from the University of Rostock in 1989 and obtained his PhD in Theoretical Physics at the Yerevan State University in Armenia in 1992. In 2002, after several post-doc positions around the world, he returned to Germany to work as a research associate and lecturer at the University of Tübingen, where he habilitated in 2006. Since 2007, he teaches at Goethe University at the Institute for Theoretical Physics and since 2017, he has the position of Fellow at FIAS.

Professorship in Armenia
He holds a professorship at the Department of Physics at the Yerevan State University in Armenia, since 2011.

Projects @ FIAS: 1

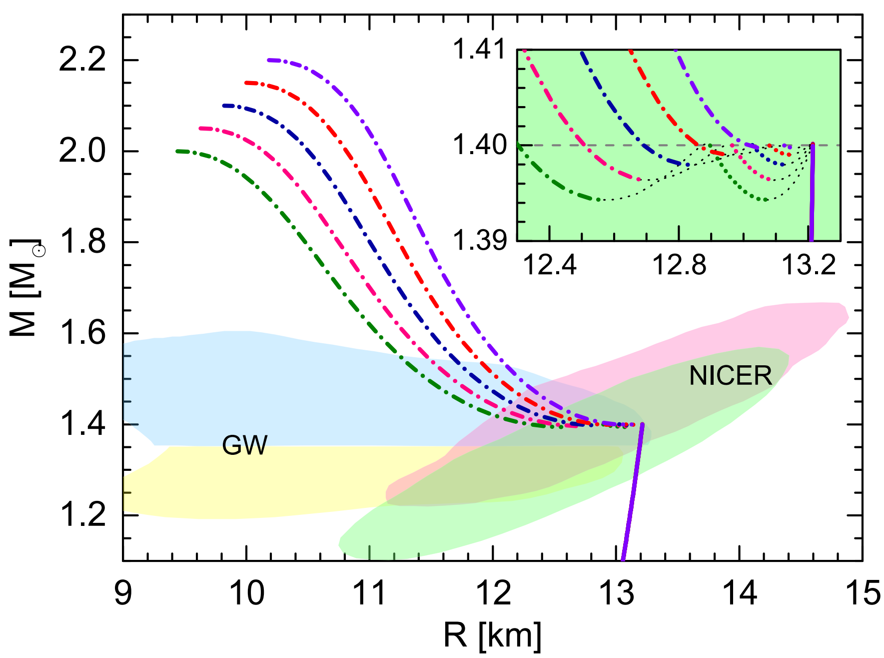
Collaborations

Prof. Mark Alford, Washington Univ.
Prof. David Balschke, Wroclaw Univ.
Prof. Kent Yagi, Virginia Univ.Prof. Vassileos Paschalidis Univ. of Arizona, Prof. Fridolin Weber, San-Diego State

Equation of state of superdense matter

During 2019, the group of A. Sedrakian worked on the equation of state of superdense matter including heavy baryons (such as hyperons, Delta-resonances) and quarks with some applications to compact stars in the binary neutron star collisions.

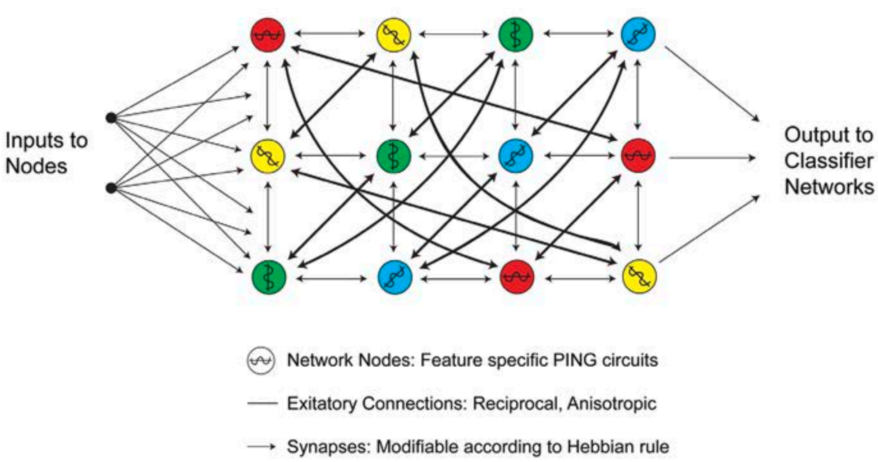
Models of such stars were constructed which are consistent with the recent astrophysical data, in particular, the famous neutron-star collision event GW170817. Furthermore, cooling of hypernuclear stars was studied as a diagnostics of composition of neutron stars interiors. Finally, a large review by A. Sedrakian and J. W. Clark on pairing in nuclear systems and neutron stars was published in Euro. Phys. J.

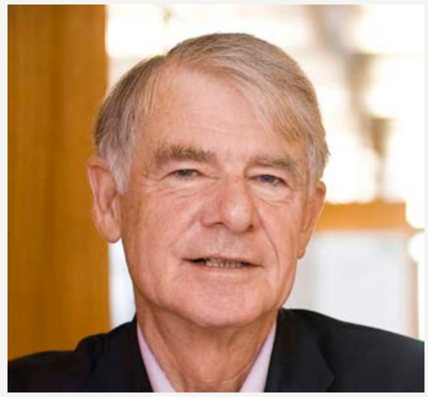


The mass-radius diagram for compact stars featuring a quark core. The model is consistent with constraints placed by the NICER experiment and the analysis of the GW170817 event. The inset shows the imergence of twin and triplet configurations - multiples stars with same masses, but different radii.

Computations in the high dimensional state space provided by the dynamics of the cerebral cortex

There is still no unifying theory of how the cerebral cortex processes information. Consequently, numerous experimentally identified phenomena, especially the extremely complex dynamics lack a cohesive theoretical framework. We formulated a hypothesis that assigns specific functions to some of these dynamic interactions. As depicted below, the visual cortex can be considered as a recurrent network, whose nodes are feature selective, have a propensity to oscillate, and are coupled through connections whose lay out and efficiency are shaped by experience. Consequently, the architecture of these connections reflects the statistical contingencies of features in the visual world. We are currently testing predictions of our hypothesis by simultaneously recording the activity of numerous network nodes in trained monkeys while these perform cognitive tasks. The results obtained so far support the following predictions. The high dimensional correlation structure of resting activity harbours the priors required for the dynamic binding of features that underlies perceptual grouping. Presenting structured visual stimuli leads to a rapid convergence of network dynamics to low dimensional sub-states with stimulus specific correlation structure. This convergence is more succinct for natural stimuli matching the stored priors than for manipulated stimuli whose statistics do not correspond to prior experience. Thus, sub-states reflect the match between sensory evidence and the stored model of the world. Classification with machine learning techniques of sub-states revealed that these are stimulus specific and better classifiable as well as more sustained if evoked by natural than manipulated stimuli. These observations suggest a mechanism that permits the dynamic representation and parallel read out of a vast amount of priors and the ultrafast comparison of sensory evidence with stored knowledge. These are essential functions of predictive coding strategies.





Prof. Dr. Dr. h.c. mult. Wolf Singer

Wolf Singer, studied Medicine in Munich and Paris, received his PhD from the LMU Munich and his habilitation at the TU Munich.
He was one of the directors of the MPI for Brain Research, as well as founding director of FIAS and the Ernst Strüngmann Institute for Neuroscience.
His research is devoted to the exploration of neuronal foundations of cognitive functions. Central to his research is the question over how many brain areas processes are connected to allow for coherent perception.

Leopoldina Member

Among many other awards, Singer is a member of the National Academy of Sciences.

Projects @ FIAS: 2

Collaborations

Dunja Bruder (HZI), Veronika von Messling (PEI), Franklin Toapanta (Maryland University), Yassine Taoufik (Hôpital Bicêtre), Frank Pessler (MHH)

Superficial layers of the cerebral cortex: A delay coupled, anisotropic, recurrent oscillator network Columns coding for related features are coupled preferentially.

**Dr.
Jan Steinheimer-Froschauer**

Dr. Jan Steinheimer-Froschauer graduated in physics in 2008 with a diploma in theoretical physics from Goethe University Frankfurt. After three more years, he earned a PhD from the Goethe University. He then received a postdoctoral position at FIAS from 2011-2012, before moving to the Nuclear Science Division of the Lawrence Berkeley National Laboratory, Berkeley, USA. Since 2013, he has been working at FIAS as a postdoc and was appointed Research Fellow in 2017.

Collaboration with China

Jan Steinheimer is one of the initiators of the Xidian FIAS International Joint Research Center established 2019.

Projects @ FIAS: 3

Collaborations

Prof. Dr. Jörg Aichelin, CNRS, Univ. de Nantes
Xidian University

Cluster finding and quantitative analysis with DL

An essential component for the study of many-body systems in physics, and especially in high energy nuclear physics, is the study of many particle correlations and clusters. Often the details of fundamental interactions can be encoded by the study of the correlations of particles produced in high energy collider experiments. For example features like phase transitions and critical phenomena will lead to very distinct correlation structures and particle clustering.

A challenge for the measurement of such correlations is often the large noise encountered in such experiments. The appearance of noise in observations is a widespread phenomenon not limited to high energy physics. As an example the above figure shows how 5 clusters of particles would show up in a measurement with small noise or large noise. Though in both cases the fraction of particles in clusters to total particles is the same, the extraction of correlation parameters would be much more difficult in the noisy case.

In this project we aim to study how Deep-neural-networks can be used to identify and quantify such clusters in the presence of noise and determine the limits of these models. In this way we intend to make the Neural Networks that are already widely used for such tasks more interpretable and the results understandable in a quantitative way.

This research is currently ongoing and part of two projects, one funded by BMBF (ErUM-data) and one research exchange with Lawrence Berkeley National Laboratory funded by the DAAD.

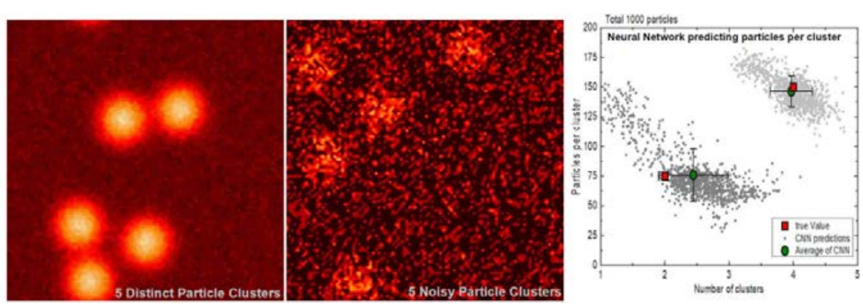


Fig. 1: Schematic picture of introducing correlations into the sub-structure

Deep Learning in theoretical Sciences

The DL and theoretical physics groups are further extending, also by new strategic hires, their expertise in Machine Learning and Artificial Intelligence, AIML, applications in science and technology, from theoretical heavy-ion physics and nuclear astrophysics, binary neutron star mergers and gravitational waves, relativistic field theory and EoS of dense, hot elementary hadron- and quark matter (supported by BMBF and in collaboration with physics and informatics departments of GU and with the Helmholtz Zentrum GSI, Brookhaven National Lab BNL, JINR Dubna and CERN) to Computational Fluid Dynamics and Valve-Pipe-Pump- networks (supported by SAMSON AG and Polytechnische Stiftung), sustainable energy and power networks (supported by BMWi and BMBF) and towards new AIML- based risk analysis of geothermal drilling (supported by BMWi) earthquake risk predictions (supported by BMBF), and methane ice exploration - in particular along the pacific ring of fire (in Indonesia and the south china sea).

The Topics were the focus of the 2019 Giersch Symposion at FIAS, with 80 top scientists attendees from all over the world.

We have strengthened and extended our strategic partnership on the above topics with the people's republic of China's Academy of Science (CAS) - institutions, in particular with UCAS, IGG and IoA, Beijing, USTC, Hefei, and the IMP Lanzhou.

We founded the Xidian-Fias international Joint Research Center XFiJRC, which is located at FIAS in the GIERSCH Science Center and is also the location of the JRC with the SCNU, Canton, which focuses on AIML applications in Jet physics.

**Prof. Dr. Dr. h. c. mult.
Horst Stöcker**

Following his doctorate 1979 at GU Frankfurt, he first became a guest researcher at GSI Darmstadt.
In 1980 Stöcker joined the Lawrence Berkeley Laboratory of the University of California, Berkeley, USA. From 1982 to 1985, he was an Assistant Professor at the Department of Physics and Astronomy at Michigan State University and NSCL.
In 1985 Horst Stöcker accepted a professorship in Theoretical Physics at the Johann Wolfgang Goethe University in Frankfurt am Main.

At FIAS since 2004

Horst Stöcker is part of FIAS since its foundation in 2004 and was its first chair of the board of directors.

Projects @ FIAS: 4

Collaborations

In the future, methods of artificial intelligence will inevitably be used in all fields of research.

**Prof. Dr.
Jürgen Struckmeier**

After finishing his diploma in physics 1978, Jürgen Struckmeier got an appointment as staff scientist at GSI in Darmstadt, where he obtained his PhD in 1985. In 2002, his habilitation thesis was accepted at the Physics faculty of the Goethe University Frankfurt. Having worked as a lecturer, he was appointed there as "Extracurricular Professor", in 2010. In 2016, he joined FIAS as Fellow.

Highlight

Before he focused on gravitational theory, Jürgen Struckmeier successfully carried out theoretical research in the field of beam dynamics in particle accelerators.

Projects @ FIAS: 1

Collaborations

P. Hess (UNA Mexico)

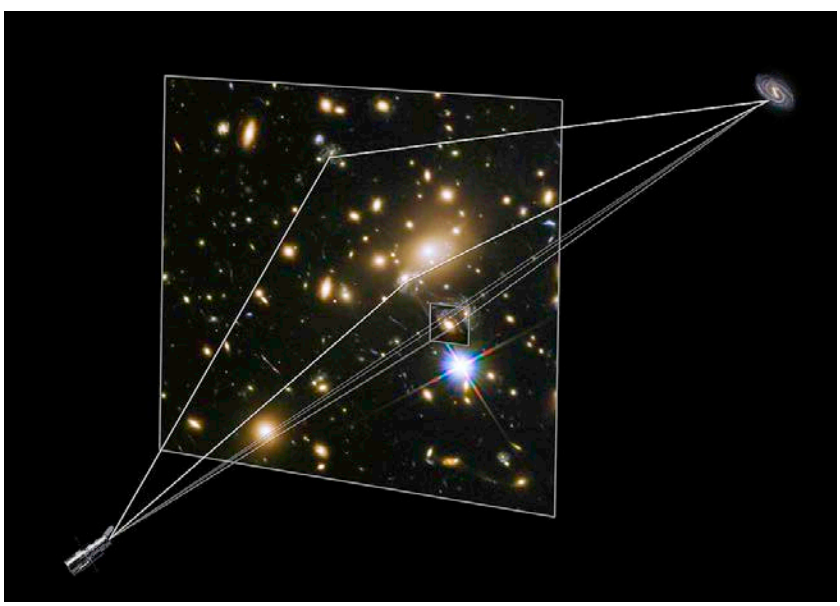
E.I. Guendelman (Ben-Gurion-University)

Covariant Canonical Gauge Theory of Gravity

Over the past 5 years the CCGG group at FIAS developed a novel semiclassical field theory of gravity and matter based on a rigorous mathematical framework, the Hamiltonian canonical transformation theory. With just a minimal set of physical postulates – namely the action principle and the principle of general relativity – this framework implements local invariance of a system of matter fields with respect to arbitrary coordinate transformations (diffeomorphism invariance). In a way similar to Young-Mills theories, new compensating gauge fields have to be introduced that turn out to be the connection coefficients on the underlying frame bundle. The now dynamical space-time is described by the connection together with the independent metric tensor (Palatini formulation), with torsion and non-metricity not a priori excluded. The CCGG framework not only unambiguously fixes the coupling of the matter fields to a dynamical space-time, but also stipulates a quadratic extension of the Einstein-Hilbert theory of gravity. Space-time is then endowed with kinetic energy and inertia, which is in line with the perception of gravity as originating from elementary particles (gravitons), while fermions acquire a curvature-dependent mass correction originating from spin-gravity interaction. These modifications have important cosmological implications: Dark energy and inflation are found to be a geometric effect related to torsion and curvature, respectively. In 2019 the group pursued the analysis of the CCGG theory focusing on three areas:

1. Detailed investigation of matter/gravity interactions in CCGG for spin-0, spin-½, and spin-1 (2 preprints, 1 publication)
2. The generic theory of geometrodynamics from Noether's theorem for the Diff(M) symmetry group (1 publication, FIAS series)
3. Cosmology (4 publications , 1 paper accepted)

Moreover, investigations of the two-measure ansatz for gravity carried out in cooperation with the Ben-Gurion University of the Negev (Israel) led to further 8 publications. The above results have been presented in 10 internal and external meetings and conferences.



This sketch by NASA shows paths of light from a distant galaxy that is being gravitationally lensed.

Theory of Neural Dynamics

My group "Theory of Neural Dynamics" at the Max Planck Institute for Brain Research is collaborating with Prof. Dr. Meyer from the Institute for Computer Science at the Goethe University as part of a project for the Center for Multiscale Modelling in Life Sciences (CMMS) of the FIAS Loewe Schwerpunkt program. This cooperation allows us to develop multi-scale analysis approaches to new and existing biological network models.

By combining mathematical, numerical and computational methods, we aim to better understand complex biological mechanisms, and to evaluate the stability and accuracy of existing models that describe these. We also work on existing models to improve their capacity to be implemented in experimental setups.

Our joint project "Construction, analysis and dimensional reduction for binary networks" is embedded in a larger interdisciplinary collaboration between various institutes in Frankfurt, whose goal is to combine multi-scale modelling and high performance computing to develop models that can be used for experimental applications.

Dr. Tatjana Tchumatchenko

Dr. Tatjana Tchumatchenko is a theoretical neuroscientist whose research focuses on modelling signal processing, synaptic, and subcellular dynamics in biological circuits. After receiving her PhD in Computational Neuroscience from the Göttingen Graduate School for Neurosciences, Biophysics, and Molecular Biosciences (Göttingen University, 2010), she completed a postdoctoral fellowship at the Center for Theoretical Neuroscience (Columbia University, 2011-2013) which was funded by the Volkswagen Computational Sciences fellowship (2011). As of 2013, Dr. Tchumatchenko is a Group Leader at the MPI for Brain Research and she became a FIAS fellow in 2017.

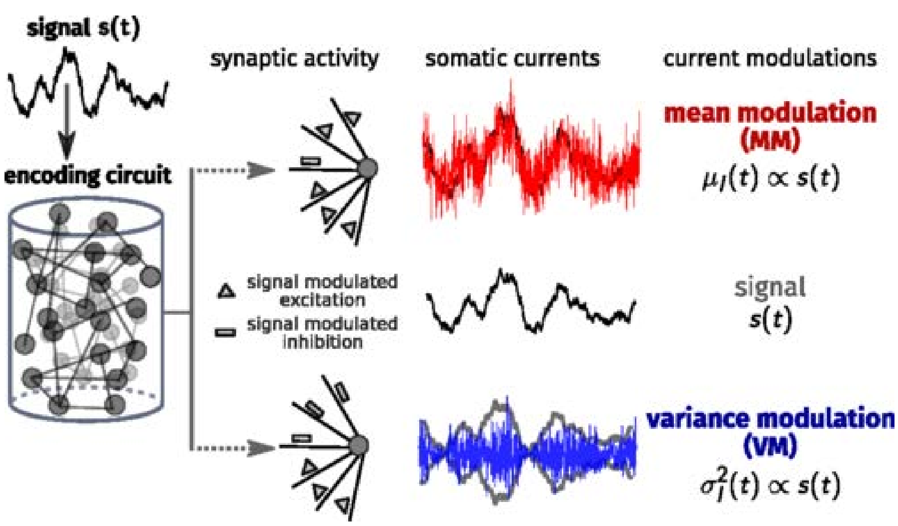
YAE Fellow

The Young Academy of Europe selected Tatjana Tchumatchenko as a new fellow in 2019

Projects @ FIAS: 1

Collaborations

Prof. Schuman, MPI Brain
Prof. Busse, LMU
Prof. Bittner, Univ. Mainz



Encoding signals by modulating either the mean or the variance of somatic input currents.
T Herfurth and T Tchumatchenko
Information transmission of mean and variance coding in integrate-and-fire neurons. Phys Rev E (2019)

Prof. Dr.
Jochen Triesch

Jochen Triesch is the Johanna Quandt Professor for Theoretical Life Sciences at FIAS. He also holds professorships at the Dept. of Physics and the Dept. of Computer Science and Mathematics at Goethe University Frankfurt. Before joining FIAS in 2005, he was Assistant Professor at UC San Diego, USA. Originally trained as a physicist, he discovered his passion for studying the brain already during his graduate education.

Active efficent coding for binocular vision

Our group has developed a new computational model to help understand the development of stereoscopic vision, which allows humans and other species to perceive the world in three dimensions through combining the two views from our left and right eyes (Eckmann et al., 2020). The model explains how the stereoscopic vision system self-calibrates in healthy conditions and how this process can fail in the presence of refractive errors, leading to amblyopia, a common developmental disorder of the visual system. The model predicts that amblyopia develops through a double vicious cycle involving two time scales (see Figure). On the one hand, disparate inputs to the two eyes trigger interocular suppression, which implies that signals from one of the two eyes are no longer processed properly by the visual cortex. This then lead to erroneous vergence and accommodation eye movements, which in turn lead to even more disparate input to the two eyes (fast timescale). On the other hand, the disparate inputs promote the development of so-called monocular neurons in visual cortex, which only respond to one of the two eyes. This in turn worsens interocular suppression, favoring the development of even more monocular neurons (slow timescale). Importantly, the model also predicts that successful treatment of amblyopia requires that visual cortex is still in a "plastic" state, where receptive fields of neurons can still adapt to the statistics of the visual input signals.

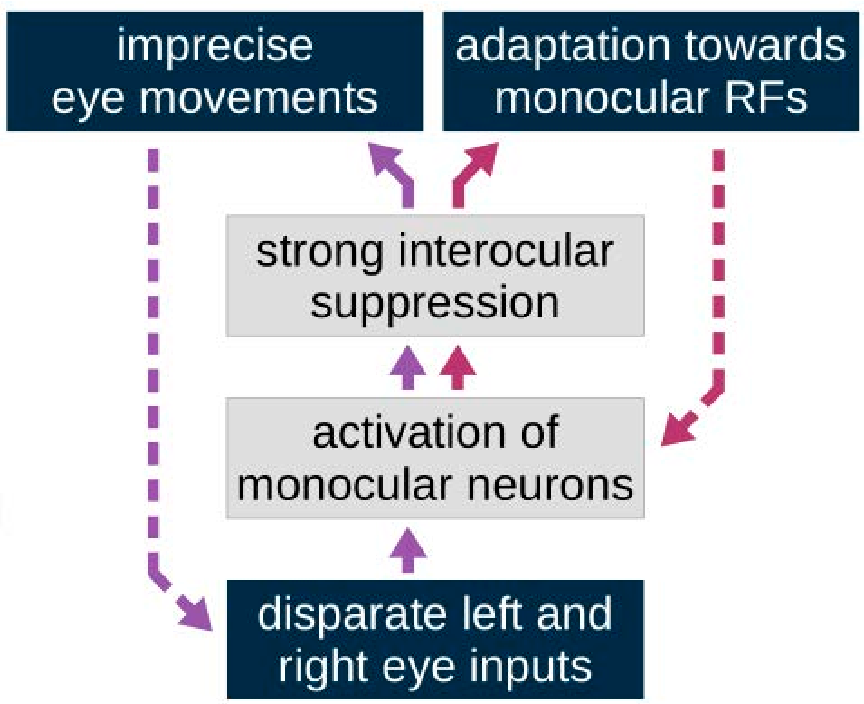
Reference: Eckmann, S., Klimmasch, L., Shi, B. E., & Triesch, J. (2020). Active efficient coding explains the development of binocular vision and its failure in amblyopia. Proceedings of the National Academy of Sciences, 117(11), 6156-6162.

Explaining Frankfurts research
In 2019 he organized a public lecture series, financed by the Stiftung Polytechnische Gesellschaft.

Projects @ FIAS: 7

Collaborations

Bert E. Shi (Hong Kong)
Maria Fronius (Frankfurt)
Monika Knopf (Frankfurt)
Ulf Ziemann (Tübingen)



Schematic picture oft the double vicious cycle involving two time scales

Systems Medicine of Infectious Diseases

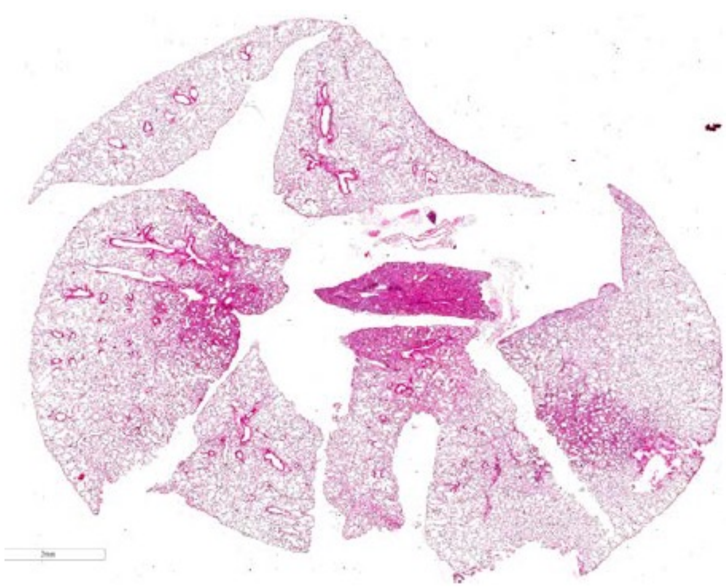
Throughout history, we have witnessed alarming high death tolls derived from infectious diseases around the globe. One of the deadliest natural disasters in human history was caused by a viral infection, the 1918 flu pandemic, which killed approximately 50 million people. Infectious diseases are latent threats to humankind - killing annually 16 million people worldwide. The spread of pathogens between infectious and susceptible hosts can be orchestrated via close physical interactions. Understanding disease transmission remains a central vexation for science as it involves several complex and dynamic processes. The link between the infection dynamics within an infected host and the susceptible population-level transmission is widely acknowledged. However, several technical aspects of the interface of within- and between-host are still in their infancy. Fusing interdisciplinary activities, the groundbreaking ambition of our research is to apply mathematical modeling and computational simulations to in vivo experiments to

(i) dissect host immune-regulatory mechanisms during acute and chronic infections, and their respective shift in the elderly;

(ii) develop mathematical models for decision making to influence the use of vaccines and drugs; and

(iii) develop multiscale epidemiological models as a virtual disease tool to evaluate therapies and public health policies during pandemics.

Our research group has a special interest in viral infections. Our collaborators are testing our simulation predictions in laboratory experiments. With the aid of the established models, it will be possible to predict rational combinations of antivirals as well as immune modulators and test them specifically. Thus, it is also conceivable that the insights gained from our research could result in therapeutic alternatives in the coming years.



Histopathological changes in the lungs of mice infected with influenza

Dr. Esteban A. Hernandez-Vargas

FIAS Fellow Esteban Hernandez-Vargas obtained a PhD in Mathematics at the National University of Ireland. Esteban held a three-year postdoc position at the Helmholtz Centre for Infection Research, Braunschweig.
In the same place, he established the Systems Medicine of Infectious Diseases research group. Since March 2017, he holds a Research Fellow funded by the Alfons und Gertrud Kassel-Stiftung, at FIAS Frankfurt.

New Professorship

Starting January 2020, he is also Professor at the National Autonomous University of Mexico (UNAM).

Projects @ FIAS: 2

Collaborations

Dunja Bruder (HZI), Veronika von Messling (PEI), Franklin Toapanta (Maryland University), Yassine Taoufik (Hôpital Bicêtre), Frank Pessler (MHH)

Dr.
Kai Zhou

Dr. Kai Zhou recieved the BSc degree in Physics from Xi'an Jiaotong University, in 2009, and his PhD degree in Physics with 'Wu You Xun' Honors from Tsinghua University, in 2014.
Afterwards he went to Goethe University Frankfurt to do postdoctoral research work at the Institute for Theoretical Physics (ITP) . Since August 2017, he is a FIAS Research Fellow focusing on Deep Learning (DL) application research.

Youngest Research Fellow

In 2017, at the age of 29, Kai Zhou became the youngest FIAS Fellow to date.

Projects @ FIAS: 3

Collaborations

XinNian Wang, Berkeley & Wuhan
Long-Gang Pang, Berkeley,
Carsten Greiner, GU
Moritz Greif, GU
Gergely Endrődi, GU
Bao-yi Chen, GU and Ti'jin
Zhe Xu, Tsinghua, Beijing
Pengfei Zhuang, Tsinghua, Beijing

Machine Learning and Artificial Intelligence

We further advanced our BMBF funded ErUM-Data project that applying Machine-/Deep-Learning to construct 'medium properties/dynamical physics-meter' for heavy-ion collisions especially CBM experiment into more realistic situations in two aspects:

(1)(with Yi-Lun Du) we included the particlization and the afterburner hadronic cascade within a hybrid simulation for the DL-EoS-meter construction, from which we found that on event-by-event basis from final particle spectra we can achieve 80% binary EoS-tpye classification accuracy while averaging events within the same centrality-bin can help enhancing the performance evidently to above 90%. These results just got accepted to publish on European Physical Journal C and online currently : arXiv:1910.11530. The results are also orally reported in Quark Matter 2019.

(2)(with newly hired PhD student: Manjunath O.K.) we included the detector simulation (with acceptance/efficiency corrections considered) for CBM experiments into the DL-analysis tool development, we constructed online impact parameter 'b-meter' with a pointnet which can directly analyze the raw track records on event-by-event basis from the detectors and shows good performance/resolution, which outperform the conventional Glauber model analysis and bypassed 'manipulation' on raw uncorrected data from experiments or event ensemble collection, This can be easily extended to other physics real time analysis and help realizing event selection as well.

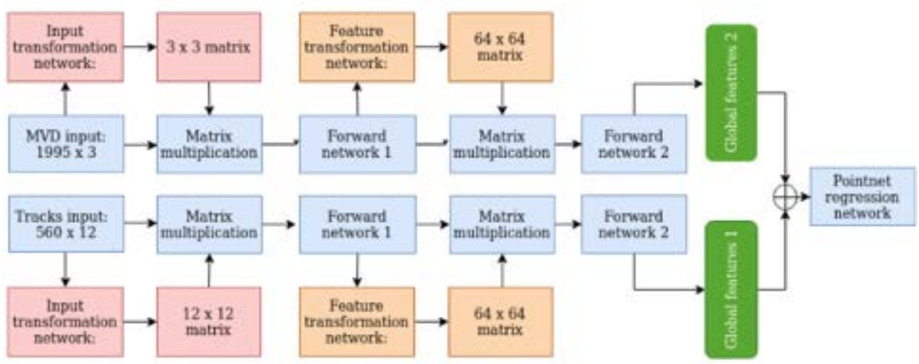


Fig. 1: Schematic picture of introducing correlations into the sub-structure

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FIAS Frankfurt Institute for Advanced Studies
Chairman Enrico Schleiff

presse@fias.uni-frankfurt.de
phone: 069 798-47688
www.fias.uni-frankfurt.de

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FIAS Frankfurt Institute for Advanced Studies
Ruth-Moufang-Straße 1
60438 Frankfurt am Main

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P16. U.Dettmar; P17. Hessentag: M.Guddorp, Award: G.Casanova; P18 Illustration FIAS/P.Vogel; P19. S.Schramm, P20. FIAS/P.Vogel, FIAS/N. Bertschinger; P21 H.Cuntz; P22. U.Dettmar, FIAS/J-B. Rose; P23. FIAS/P.Vogel, FIAS/N.Flinner; P24. FIAS/M-L. Hansmann, P25. S.Hossenfelder, NASA, ESA/D.Pestana & R.Villaverde; P26. FIAS/P. Vogel, FIAS/M.Kaschube; P27 U.Kebschull, Pixabay/geralt; P28. I.Kisel, STAR-Collaboration, CBM-Collaboration, P29. V.Lindensruth, ALICE-Collaboration, P30. P. Benjamin, F.Matthäus; P31. FIAS/P.Vogel, FIAS/I.Mishustin: P32. P.Nicolini; P33. A.Schwander, E.Schleiff, P34. FIAS/P.Vogel, FIAS/A. Sedrakian; P35 W.Singer, P36. J.Steinheimer, P37 U.Dettmar, Pixabay; P38. FIAS/P.Vogel NASA/ Hubble, P39. T.Tchumatchenko, P40. J.Triesch: P41. E.A.Hernandez-Vargaz; P42. FIAS/P.Vogel, FIAS/K.Zhou

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science for the reality of tomorrow