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JUNGE AKADEMIE MAGAZIN

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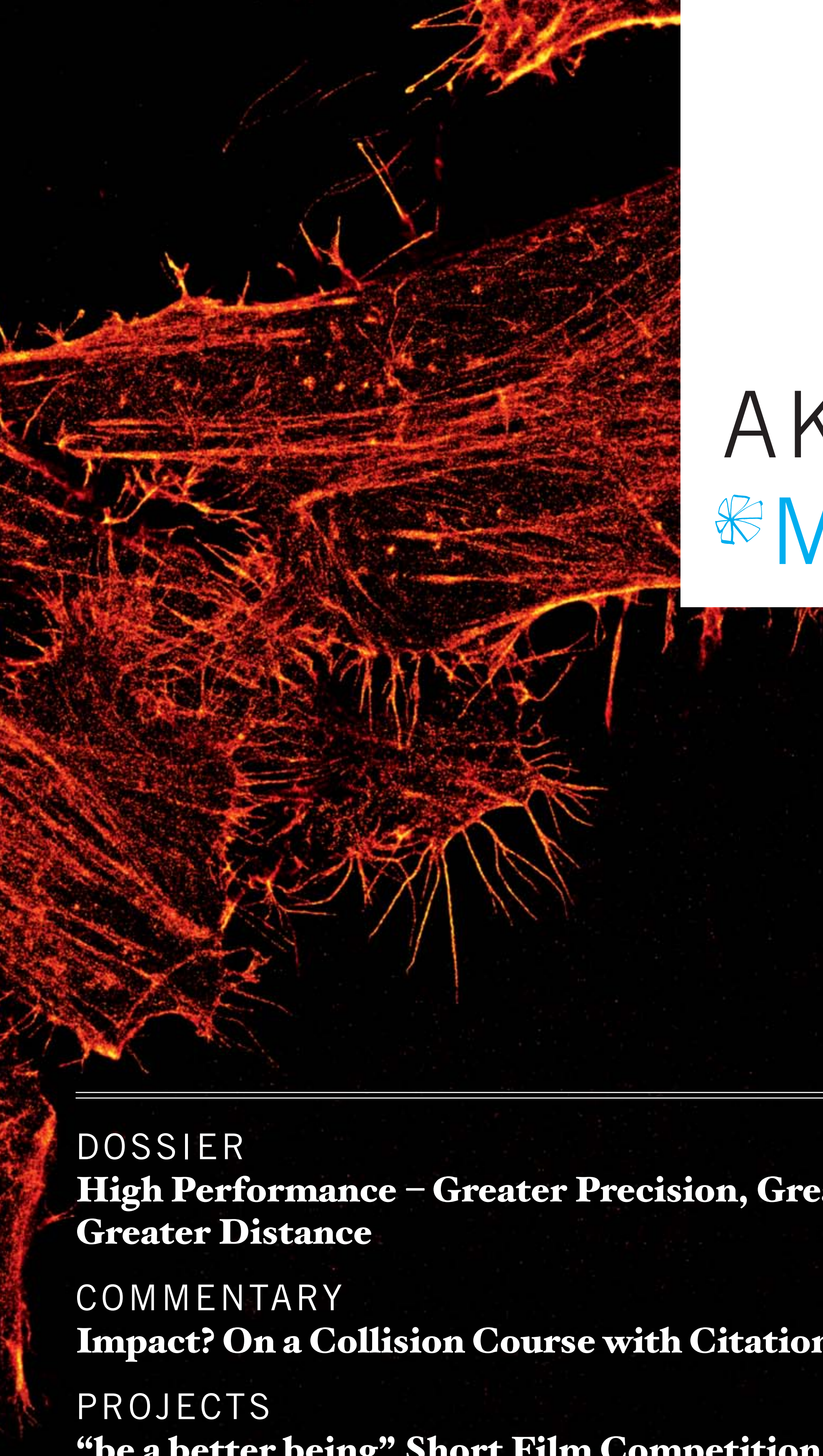

DOSSIER

High Performance – Greater Precision, Greater Speed, Greater Distance

COMMENTARY

Impact? On a Collision Course with Citation Parameters

PROJECTS

“be a better being” Short Film Competition

JUNGE AKADEMIE MAGAZIN

The *Junge Akademie Magazin* was conceived by members of the *Junge Akademie.* It provides insights into projects and events of the *Junge Akademie,* reports on members and publications, and intervenes in current academic and science policy debates.

THE *JUNGE AKADEMIE*

The *Junge Akademie (JA)* was founded in 2000 as a joint project of the Berlin-Brandenburg Academy of Sciences and Humanities *(Berlin-Brandenburgische Akademie der Wissenschaften – BBAW)* and the German National Academy of Sciences Leopoldina *(Deutsche Akademie der Naturforscher Leopoldina)*. It is the world's first academy of young academics. The Junge Akademie is co-owned by both academies, the BBAW and the Leopoldina. Since 2011 it has been firmly supported administratively within in the Leopoldina's budget and funded by the Federal Ministry of Education and Research *(Bundesministerium für Bildung und Forschung)* and the states of Berlin, Brandenburg and Sachsen-Anhalt. Its fifty members, young academics from German-speaking countries, engage in interdisciplinary discourse and are active at the intersection of academia and society.

EDITOR'S LETTER

The amount of scientific knowledge in the world continues to increase at breakneck speed. Our knowledge is growing exponentially and, at current rates, will double about every five to ten years. What seemed technically impossible yesterday has already become reality today. Never before have we been able to gaze so far into the cosmos, manipulate genetic material so precisely and easily, or process and share data so quickly.

In this edition of the *Junge Akademie Magazin*, we take you on a journey into the world of scientific high performance, where our members are helping to shape the technology of tomorrow. Biophysicist Ulrike Endesfelder employs high-definition microscopy to gain spectacular insights into living cells. Computer scientist Dirk Pflüger talks to us about the challenge of building a functioning supercomputer out of hundreds of thousands of processors. Bioinformatician Bettina Keller and cosmologist Fabian Schmidt explain how these supercomputers can be used to simulate the atomic movements of proteins and to map the structure of the universe. Atmospheric physicist Bernadette Weinzierl and musicologist Miriam Akkermann discuss the future of weather forecasting.

High performance can, however, also come with a dark side. In the *Junge Akademie's* film competition 'be a better being', numerous entries dealt with the pursuit of and pressure for constant self-improvement in the academic world and in society.
Meanwhile, there is ever more pressure on individual researchers to quantify their performance; we delve further into this topic and suggest ways in which early career researchers can deal with this development in the commentary section.

We hope you enjoy this issue of the *Junge Akademie Magazin*. The pressure is now on us to finish the next one!

Tobi J. Erb

High Performance Computer at the University of Stuttgart

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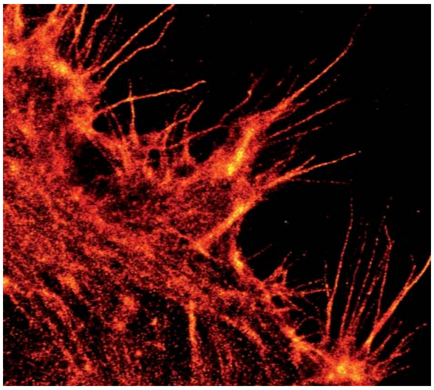
CONTENTS

HIGH PERFORMANCE – GREATER PRECISION, GREATER SPEED, GREATER DISTANCE

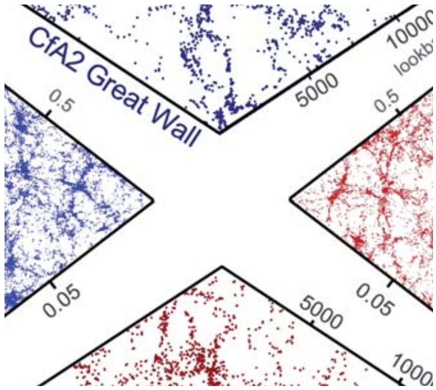
CONCEPT TOBIAS J. ERB

For many people, the first thing they associate with the term 'high performance' is top athletes. Words such as higher, faster, further come to mind. Researchers engage in high performance activities every day in order to explore new scientific terrain. In this dossier, our authors, who are all members of the *Junge Akademie,* share their stories about how supercomputers or the latest generation of microscopes help them make new discoveries.



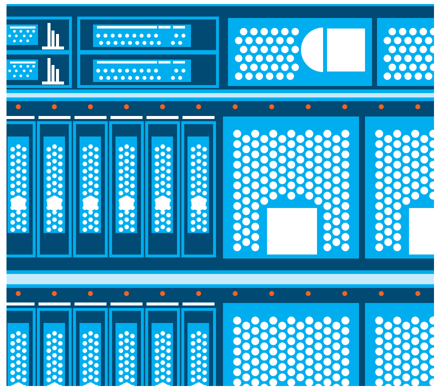
‘We can look at a living cell and measure what percentage of the RNA polymerases is transcribing a section of DNA at a given moment’,
explains Ulrike Endesfelder
(page 7).

***‘Bdellovibrio bacteriovorus*, a predatory living bacterium that feeds off other bacteria and which moves at a speed of about 150 body lengths per second.’,**
reports Thomas Böttcher
(page 14).



‘What calculations are so complicated that you would need hundreds of thousands of processors at one time?’
Bettina Keller and Fabian Schmidt give us the answer
(page 18).

‘what will happen if specific genes are deleted or certain proteins deactivated? Causal methods are of interest here’,
explains Jonas Peters
(page 24).



‘We are now at a point where we are still dealing with a bottleneck, except that it no longer occurs in the calculation process, rather in the communication network and the processors’ ability to access memory.’
writes Dirk Pflüger *(page 16)*.

‘Many research developments occur at a time when it’s not yet clear what practical application the discovery may have’,
notes Bernadett Weinzierl
(page 26).

PHOTOS: DAVID VIRANT, RESEARCH GROUP ENDESFELDER IN COOPERATION WITH RESEARCH GROUP ROTHBAUER, TÜBINGEN, V. SPRINGEL, C. S. FRENK AND S. D. M. WHITE, NATURE (LONDON) 440, 1137 (2006), „LE GUIDE DES CITÉS“ BY FRANÇOIS SCHUITEN © CASTERMAN S.A, ANDREA SCHÄFER

With the help of different mirrors, red, green and blue laser beams are layered over one another before being bundled into a single beam within the fluorescent microscope. They are used to make previously marked proteins fluoresce. This method enables researchers to examine individual elements and the structure of a cell.

PHOTO: U. ENDESFELDER

'WE'RE ABLE TO WATCH GENETIC CODES COPIED RIGHT IN FRONT OF OUR EYES'

Biophysicist Ulrike Endesfelder talks to JAM about fluorescence microscopy and its revealing insights into the inner life of living cells

INTERVIEW DIRK LIESEMER | PHOTOS ULRIKE ENDESFELDER

THE BIOPHYSICIST

Ulrike Endesfelder conducts research at the Max-Planck-Institute for Terrestrial Microbiology & the LOEWE Centre for Synthetic Microbiology in Marburg. She joined the Junge Akademie *in 2015.*

PHOTO: LAACKMAN, MARBURG

JAM: At first glance, the images from the microscope look like spectacular photos taken in space. What exactly do these pictures show?

Ulrike Endesfelder: What you see are proteins that have been made to artificially fluoresce. This allows us to identify different molecules in the cell, for example to see what the cell skeleton looks like, how it is structured and stabilised. The pictures also show that some proteins are used in a targeted manner to transport something from A to B. In one of the pictures, you can see RNA polymerase at work - the protein that transcribes our genetic information. The fluorescence microscope also allows us to observe live how new proteins are built from this transcript.

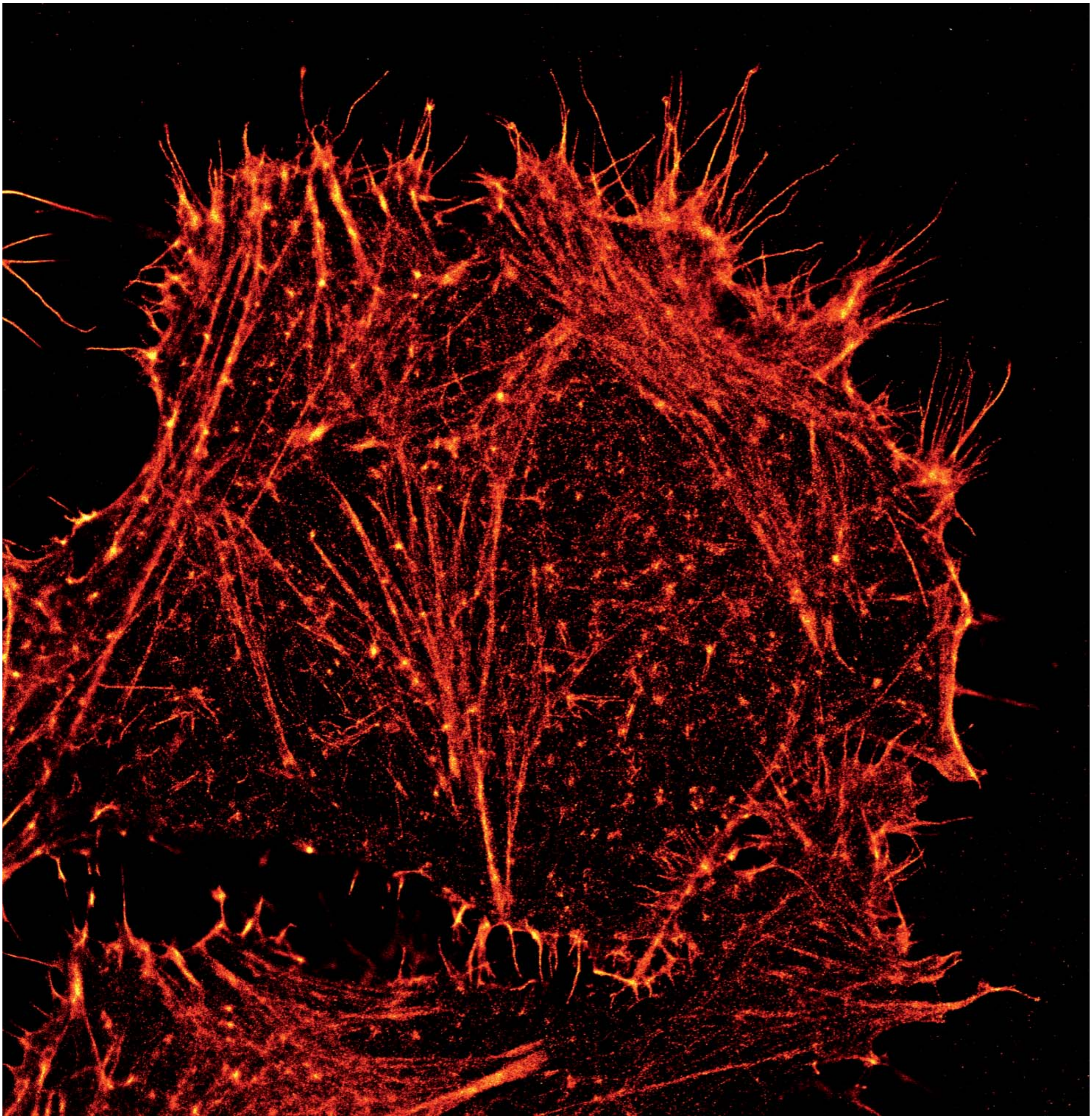
JAM: You've been studying sub-cellular cell structures and dynamics with the help of super-resolution fluorescence microscopes since 2008. What are you hoping to learn?

Ulrike Endesfelder: When we started the project, super-resolution fluorescence microscopy was still new. We were not familiar with all of the abilities of the microscopes or whether we'd be able to take three-dimensional or multi-colour pictures. We also explored the maximum possible resolution we'd be able to achieve in the pictures. The great advantage of this type of microscopy lies in the fact that these microscopes allow us to not only take detailed images of cell structures, but also to observe the dynamic processes within living cells: how a cell divides and is regulated, or the transcription and replication of DNA. It was generally known which proteins play a role in these

The RNA polymerase protein fulfils a specific task; in the case of Escherichia-coli bacteria, it reads the genetic code and creates a short transcript, enabling new proteins to be built in other parts of the cell. With the help of super-resolution microscopy, it is possible to observe individual RNA polymerases at work within living cells. This in turn allows researchers to understand when, how quickly, and where a part of DNA is transcribed.

PICTURE: U. ENDESFELDER

PICTURE: DAVID VIRANT, RESEARCH GROUP ENDESFELDER IN COOPERATION WITH RESEARCH GROUP ROTHBAUER, TÜBINGEN



Actin cytoskeleton of a human cell: the structural protein actin polymerises into dynamic filaments (fibres). In doing so, it builds a large, interconnected network and forms an essential part of the cell skeleton of eukaryotic cells. It functions as a stabilising and dynamic scaffold for the external cell shape. With the help of small cell protuberances, the cell is able to move into a specific direction or establish contacts to another cell. Vesicles (very small round or oval shaped bubbles) can also be transported along the actin net to the membrane.

processes and their general mode of interactions, but now we can observe living cells and measure which proteins are located where and at what time.

JAM: Thus many of your findings today would not have been possible without these microscopes?

Ulrike Endesfelder: Much of that research would certainly have been far more difficult. One important prerequisite for our high-performance microscopy was the discovery of the green fluorescent protein, or GFP for short. This protein is a natural fluorophore taken from jellyfish and can be made to glow through light excitation, which in our case is provided by lasers. Scientists managed to extract the protein code from a jellyfish and realised that it can be attached as a genetic marker to almost every target protein in many different kinds of organisms. When the GFP is exposed to laser beams, the protein lights up. This allows us to see exactly where the GFP-marked protein is within the cell, what structures it's building, and how it moves around. Thanks to fluorescent proteins such as GFP, observing living cells has become possible and even routine.

JAM: How much more exact is this type of super-resolution microscopy?

Ulrike Endesfelder: In classic microscopy, it's possible to depict structures at a resolution of up to 200 to 300 nanometres. Smaller details such as proteins or tiny substructures that are closer together cannot be distinguished by these microscopes. To compare: a bacterial cell may be only 500 nanometres wide. One can identify a cell, but not the place within the cell where a specific protein is located. Is it on the membrane or in the middle of the cell? Super-resolution fluorescence microscopy enables us to visualize structures that are only 10 to 20 nanometres in size.

JAM: When you compare earlier images with those taken by super-resolution microscopes, you get the impression that someone has sharpened the focus.

Ulrike Endesfelder: That's right! Today's images have high contrast and image resolution. Both of these factors lead to well perceptible images. The contrast in earlier images was already very good, but now the resolution is about ten times better than before.

JAM: Super-resolution also means that this type of microscopy is also extremely sensitive.

Ulrike Endesfelder: That's why our microscope is kept in the basement, where – in comparison with the higher storeys – there are fewer vibrations, such as those caused by doors being slammed shut. Every tiny movement, even if you can't see it with the naked eye, can lead to a shaky image in the microscope. That's why the optical table holding all of the equipment is cushioned with compressed air, well isolated from the surroundings.

JAM: You work with lasers in order to activate the fluorophores in the cells. How advanced is this technology?

Ulrike Endesfelder: In my lab, for example, we're working with six different laser colours. We can activate some fluorophores with blue-wavelength light, others with green or red. That allows us to differentiate between the proteins and to observe them together at one time. For the most part, producing images with the microscope works just like a normal digital camera with a CCD chip, except that our technology is decidedly more sensitive. This allows us to identify individual fluorophores that are emitting just a few thousand photons of light.

JAM: Do we know things now that we did not yet know in 2006, when super-resolution microscopy was just emerging?

Ulrike Endesfelder: In my work, I was able to measure how many RNA polymerases – the proteins that transcribe DNA – exist within a specific cell. Previously we lacked the necessary image-producing, quantitative microscopy. Now I can tell you what this cell looks like, where exactly the RNA polymerases are found within the cell, and how many of them there are. We can look at a living cell and measure what percentage of the RNA polymerases is transcribing a section of DNA at a given moment, and what percentage is already searching for a new section. In other studies, we are looking at how more complex structures are made up of many proteins, what their spatial arrangement looks like, and how their geometry changes under certain circumstances. It is possible to observe all of this in the cells themselves, even in living cells. None of this would be possible using in-vitro experiments.

JAM: And by the time you've found one answer, new questions have already appeared. What are you working on right now?

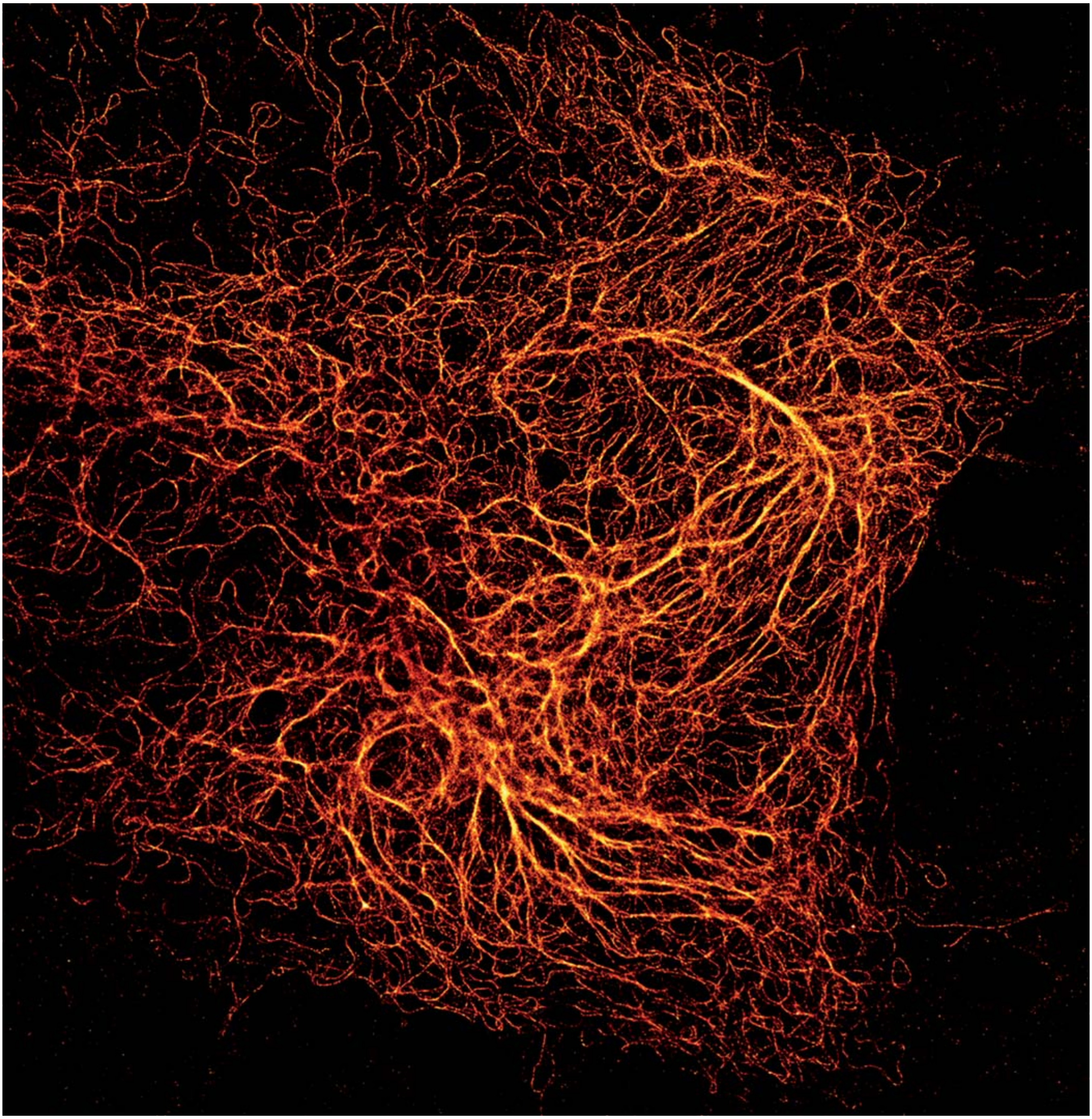
Ulrike Endesfelder: One central question I'm pursuing is what impact the presence of the fluorophores is possibly having on the proteins. After all, the fluorophores are not native to the cell, they're brought in from outside. Right now, the general assumption in the researcher community is that the smaller a fluorophore is, the less it disturbs the cell. That's why there's a trend towards using ever smaller, more compact marking strategies. Scientists are also trying to use lower laser illumination powers, as there are processes that are very sensitive and as a result are quickly affected. We're also becoming more careful with the wavelength of the light being used: fluorescent proteins are often photo-activated with the help of UV light, which is not very gentle. That's why you're not supposed to spend hours in a tanning bed. We're currently preparing a study for publication in which we show that it is also possible to use longer wavelengths and therefore lower-energy light to photo-activate fluorescent proteins. Our goal is to observe the normal behaviour of a cell, and not to provoke a protective or emergency reaction.

JAM: Does combining different microscopes hold any promise for your work?

Ulrike Endesfelder: We often combine our super-resolution microscopy studies with biochemical or spectroscopic methods. This allows us to first observe how a larger cell population behaves as a whole, and then move on to studying the subcellular structures. Or, I'll combine fluorescence and electron microscopy. The latter enables us to better identify wider contexts due to its high resolution of the entire ultrastructure. But this process is not suitable for living cells. With fluorescence microscopy, we are able to tag and observe two or three specific proteins. When you overlay the images from the two microscopes, you obtain very detailed pictures and can immediately recognize the larger context of the individual proteins' organisation.

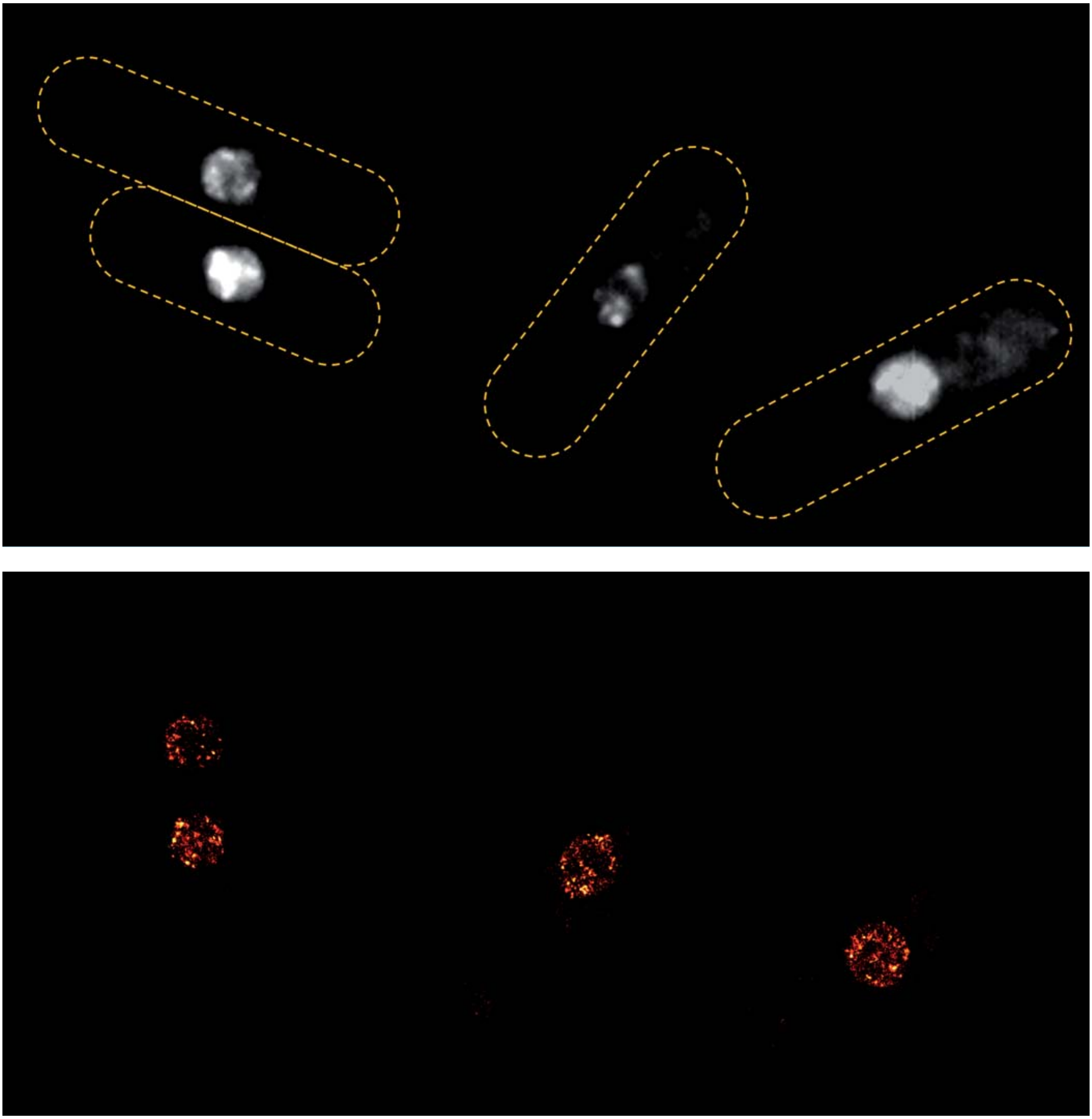
JAM: If you were to summarise your findings: do processes in a cell occur in a random or an organised fashion?

Ulrike Endesfelder: I often work with bacteria and yeast. Yeast cells have a cell core and high spatial organisation, which points to organised processes. In bacteria cells, on the other hand, there are no clear cellular compartments. For a long time, scientists believed that all processes within a bacterium occur simultaneously and without any spatial organisation. Today we know that intracellular processes within a bacterial cell are very precisely coordinated. The proteins do not distribute themselves evenly throughout the cell, but are structurally organised. So now the big question is: who is regulating whom?



A vimentin network in a human cell: like actin, vimentin is a structure-building protein of the cytoskeleton in eukaryotic cells, one of the so-called intermediary filaments. It plays an important role in the organisation of organelles in the cytosol and is tied to the cell core, the endoplasmic reticulum, and the mitochondria. It is a primary focus of current research due to its diverse and not yet fully established functions.

PICTURE: DAVID VIRANT, RESEARCH GROUP ENDESFELDER IN COOPERATION WITH RESEARCH GROUP ROTHBAUER, TÜBINGEN



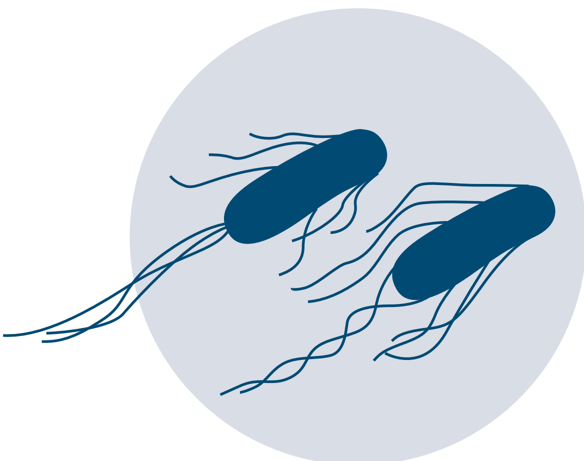
PICTURE: DAVID VIRANT, RESEARCH GROUP ENDESFELDER

The nuclear, DNA-binding protein cbpI, visible here in the cell core of individual Schizosaccharomyces pombe yeast cells, has multiple functions. On the one hand, it is part of the kinetochore, a multiprotein complex that regulates every cell division and connects the DNA to the microtubule of the spindle apparatus. On the other hand, the protein binds to starting points of replication as well as to transposons, which points at further regulatory functions.

FASTER THAN A PEREGRINE FALCON

Many of the most astonishing records in nature are found where we least expect them: in the microbial cosmos

TEXT THOMAS BÖTTCHER



Escherichia coli

High performance is often associated only with technical achievements by humans or creatures in the macrocosm. And yet it is the smallest life forms, those invisible to the naked eye, that manage to beat most records from the plant and animal kingdoms. Single-cell microbes such as bacteria, fungi, and archaea have long been and today remain the rulers of our planet.

A single gram of soil can contain more microorganisms than there are people on earth. However, it is not simply the sheer number and diversity of these microorganisms that is so surprising. They have managed to colonise every corner of our planet and almost every type of environment, no matter how inhospitable: from hydrothermal vents (where the temperature can reach up to 122 degrees Celsius) all the way to permafrost; from boiling acid springs to highly alkaline lakes, saturated saline solutions, and mine water rich in heavy metals. Microbial life can prosper in places where many more complex lifeforms would have no chance of survival.

This success is in large part due to the short generation times of microorganisms and their consequent rapid adaptability. For example, even the ordinary intestinal bacterium *Escherichia coli* divides every 20 minutes, thereby nearly hitting the thermodynamic efficiency limit. Further out on the spectrum, a thermophile bacterium (Strain TR10) from the hydrothermal springs of Lake Tanganyika in East Africa demonstrated a record-breaking duplication rate of just 10 minutes in its optimal growth temperature of 60 degrees Celsius.

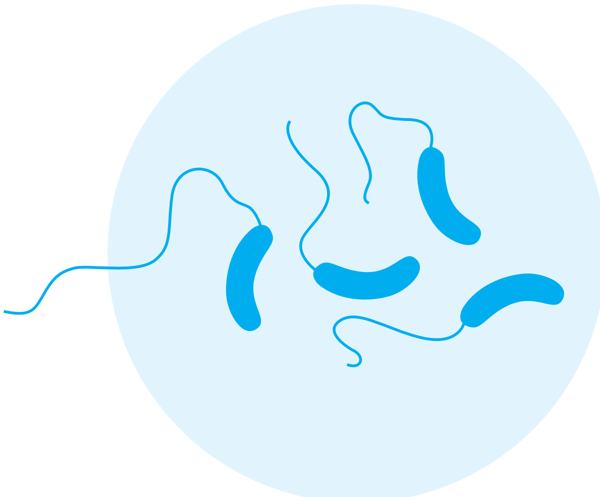
Such a rapid rate of reproduction in a cell requires absolute peak performance in terms of efficiency and coordination. It means that the entire genetic information of a cell must be copied, read, and carried out in all of its coded functions within just a few minutes. During this process, high performance enzymes take the slightly more than 4.6 million individual base pairs of the bacteria's genome from their building blocks and place them into the correct order, whereby every single enzyme achieves a top speed of a thousand reactions per second. Simultaneously, other enzymes read the more than four thousand genes and translate these into RNA and proteins.

In just a few minutes, the cell produces nearly ten million new proteins, which in turn produce billions of smaller molecules that provide enough energy for the cell and synthesise their own building blocks for proteins and nucleic acids, sugars, and constituents of the cell membrane and cell walls. This requires precise coordination of the metabolic pathways and enzymes in order to achieve maximum throughput with the utmost precision.

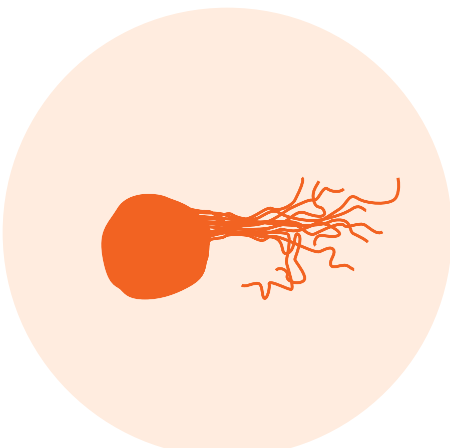
These processes all take place within a bacterial cell that is only a few thousandths of a millimetre in size. But this does not mean that our "littlest ones" have reached the limits of their abilities, not by any means! Many microorganisms produce substances as side products that are of great value to us: antibiotics, vitamins, and a great wealth of pharmacological ingredients. Microorganisms also play an essential part in fermentation processes and are therefore used not only in the production of foodstuffs including yoghurt, cheese, sausage, alcoholic beverages, and vinegar, but also in fuels such as methanol, ethanol, and hydrogen. It is only with the help of genetically tuned bacteria that we are able to mass produce insulin, interferon and fine chemicals.

Microorganisms achieve top performance in ways that go beyond their role as producers for biotechnology. So, for example, some bacteria possess tiny motors that can easily compete with the latest human technology. These bacterial motors are anchored within the membrane of the bacterial cell and are connected to extremely long, cable-like protein filaments called flagella. The motor turns the flagella like a giant, whip-like propeller and moves the cell forward. This enables microorganisms to swim in liquids or to swarm across moist surfaces, as well as change direction in response to chemical stimuli. Flagella thus represent a type of outboard motor in the bacterial world.

These motors are capable of incredible performance. While a modern outboard motor produces about five thousand rotations per minute, the flagellar motor of the bacterium *Vibrio alginolyticus* has been measured to produce top speeds of up to a hundred thousand rotations per minute, the equivalent of ten times the rotational speed of a jet motor in the aviation industry. With the help of these high-performance motors, bacteria obtain a push that can move them up to a tenth of a millimetre per second. Considering that bacteria are only a few thousandths of a millimetre in size, it is extraordinary that they are able to achieve such speed in relation to their body length.



Bdellovibrio bacteriovorus

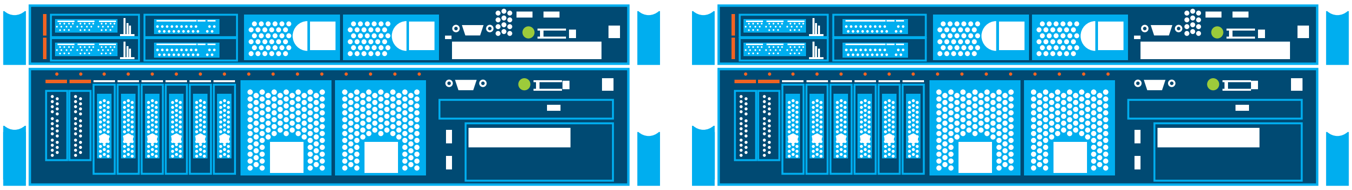


Methanocaldococcus villosus

Further examples of this phenomenon include *Bdellovibrio bacteriovorus,* a predatory living bacterium that feeds off other bacteria and which moves at a speed of about 150 body lengths per second. Then there is *Methanocaldococcus villosus,* a methane-producing representative of the archaea that feels particularly at home in hot deep-sea springs and achieves top speeds of up to 500 body lengths per second. It is likely that its speed results from adapting to the intense local fluctuations in temperatures and availability of nutrients in the bacterium's environment. To compare: the fastest mammal on land, the leopard, achieves a mere 20 body lengths per second. Not even the peregrine falcon, the fastest animal in the macrocosm, can keep up. The peregrine falcon's top speed of 389 kilometres per hour, achieved in a nosedive from a height of about five kilometres, corresponds to around 300 body lengths per second, leaving the peregrine falcon lagging far behind the tiny *Methanocaldococcus villosus.* Which just goes to show that you don't have to look all that high to find top performance.

Thomas Böttcher works in the Department of Chemistry at the University of Konstanz and joined the Junge Akademie *in 2015.*

ILLUSTRATION: WIEBKE GENZMER



93 000 000 000 000 000 COMPUTATIONS PER SECOND

Every new generation of supercomputers has so far outperformed the previous. But as we reach the performance limits of individual processors, manufacturers and users face ever increasing complexity.

TEXT DIRK PFLÜGER

Let's travel back in history for a brief moment. The word 'computer' was originally the job title for a person who carried out calculations: the first time the phrase 'a computer wanted' was used was in a 1982 job advert from the US Marines published in the *New York Times*. The requirements stipulated in the ad included: knowledge of algebra, geometry, trigonometry, and astronomy.

The term 'supercomputer' was coined upon the introduction of the first electronic computers. A supercomputer was a machine capable of performing calculations faster than a human. The performance of supercomputers grew rapidly. Gordon Moore, co-founder of Intel, formulated his famous 'law' in 1965. According to Moore's Law, to put it in layman's terms, the computational power of computers doubles every two years – an observation that for the most part remains true to this day. For computer buyers, this means that the next computer of similar size (measured in volume or money, we are not being all that precise here), would be capable of higher performance. If a program runs too slowly, all users have to do is wait for the next generation of computers to arrive.

The scale of this performance boost can best be illustrated using a 'what if' thought exercise. Take, for example, a VW Beetle from 1970 with a top speed of 130 km/h, i.e. 36 metres per second. If its acceleration had increased at the same rate as that of the computer, then it would have broken the sound barrier by 1977 and would today be capable of travelling at the speed of light. By 2030, our VW Beetle would leave the Starship Enterprise (with its speed of Warp 5 or 125 times faster than the speed of light) in the dust, travelling at more than 4.7 x 10^{10} metres per second (equivalent to 2.2 x 10^{11} km/h).

At the same time, Moore's Law also means that computers will continue to shrink in size while maintaining the same level of performance. Thus massive machines have been shrunk down to easily manageable boxes known as personal computers, which have continually improved in terms of performance, or have been replaced by even smaller devices.

But what happened to the class of enormous machines, those that did not shrink but continually improved in terms of performance? The machines that Thomas Watson, president of IBM, probably had mind in 1943 when he predicted: 'I think there is a world market for maybe five computers?'. Well, they certainly do still exist and there are definitely more than five of them. Twice a year, these supercomputers or high-performance computers are ranked in the Top500, the list of the 500 fastest computers used worldwide for civilian purposes. The Linpack Benchmark is used to measure the number of calculations per second for a selection of linear algebraic routines such as solving a large system of equations or matrix-vector multiplication – which are all core tasks of the original human 'computer'. To put it into context: the computational power of the largest supercomputers is

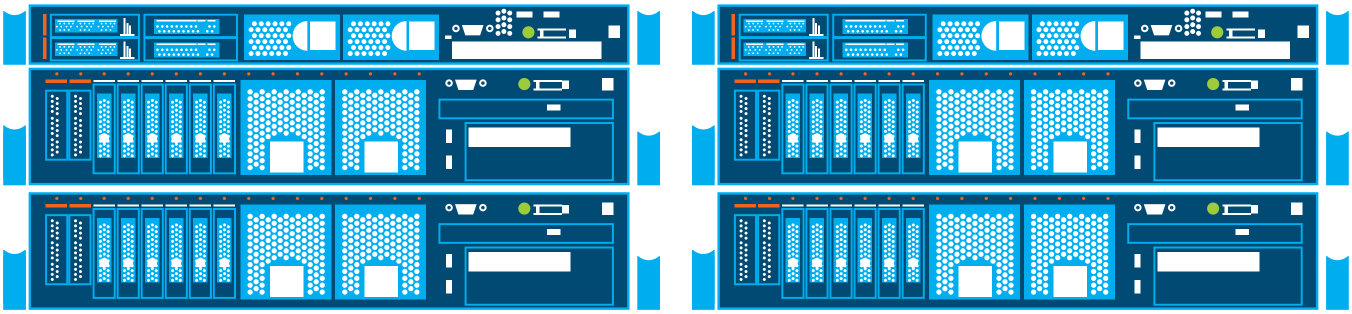


ILLUSTRATION: WIEBKE GENZMER

typically equivalent to about ten thousand PCs (each of which has the computational power of a supercomputer from 20 years ago).

The current number one? That would be the Chinese computer Sunway TaihuLight, which possesses more than ten million computing units and achieves 93 trillion calculations per second, which is practically unimaginable (that's 93 with 15 zeros after it). If every single one of the 7.5 billion people on earth managed to solve 12.5 million calculations per second (the performance level of a supercomputer at the end of the 1960s), then that would be equivalent to the performance of the Sunway TaihuLight.

The architecture and operation of a supercomputer are no trivial matter. Such a machine consumes 15 megawatts of power, which is equivalent to the energy needs of about 31,000 four-person households in Germany in 2016, and almost one percent of the net power output of a modern nuclear power plant. At a cost of 25 cents per kilowatt hour, the total energy bill comes to 32 million euros per year! Taking a supercomputer's operational life into consideration, the acquisition costs are no longer the most critical factor in comparison with the cost of running it.

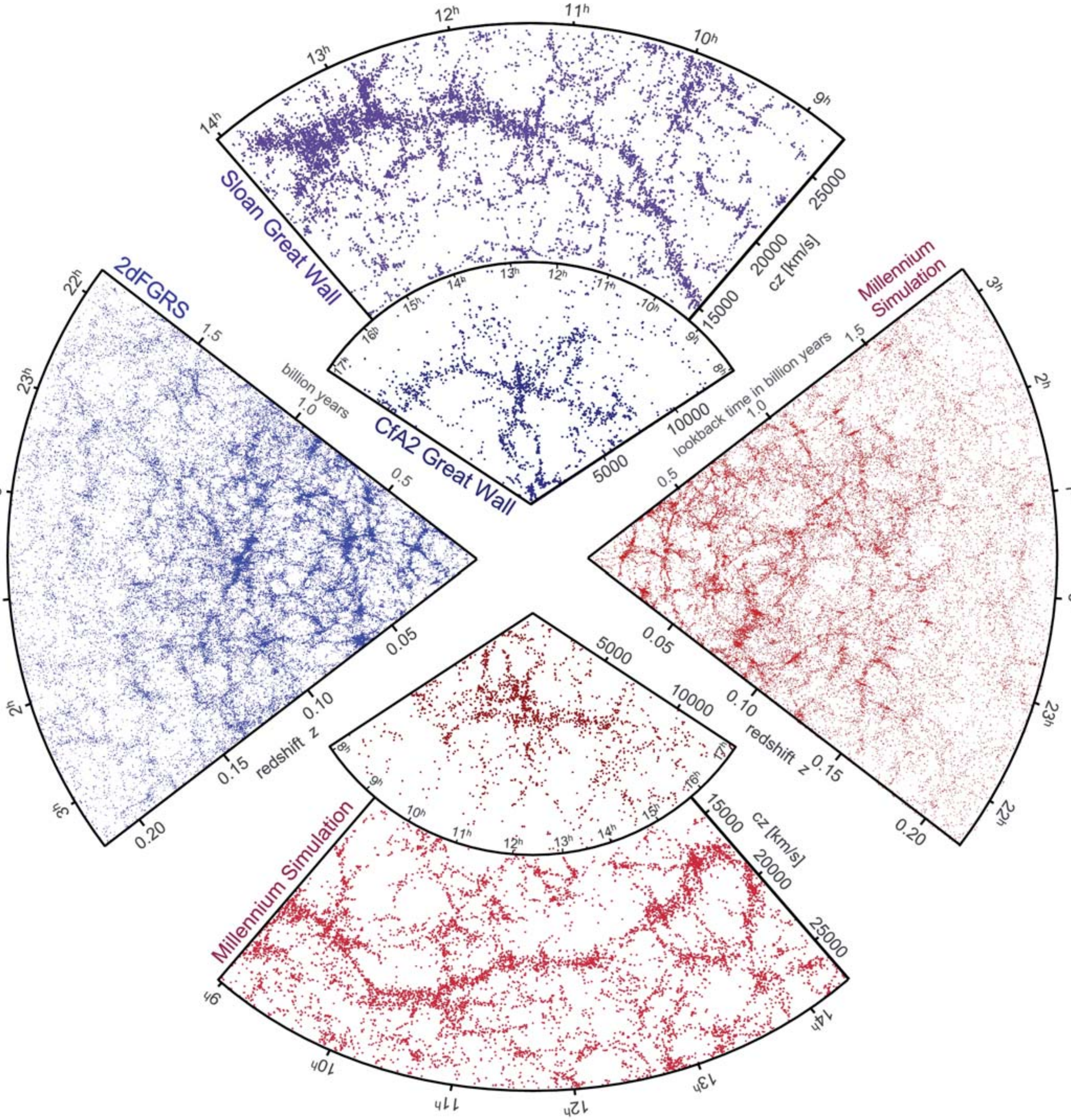
When it comes to running a supercomputer, the challenge lies not just in the fact that ten million processing units need to be supplied with power and cooled, but that they also need to be able to store information and be connected with each other. Finally, the computational tasks must be allocated in such a way that all units are at work simultaneously. So then, why not use fewer processors that can work faster? Seymore Cray, computer pioneer and father of many supercomputers, explained it like this: 'If you were plowing a field, what would you rather use? Two strong oxen or 1024 chickens?'. One single faster processor is easier to manage than many slower ones.

One issue here is the fact that the speed of individual processors has not increased for more than ten years now. The level of miniaturisation possible within the manufacturing process has reached its physical limits. The only reason Moore's law is still valid today is because ever larger numbers of processors are being deployed together. As William Gropp and his colleagues noted in a paper, 'to pull a larger wagon, it's easier to add more oxen than to breed one giant ox'.

Nowadays, increasing parallelism is the main focus of many research questions in high-performance computing. Or, in other words: how do you pull a wagon with hundreds of thousands of oxen? Doing so will require rewriting simulation programs and developing new mathematical procedures and algorithms. We are now at a point where we are still dealing with a bottleneck, except that it no longer occurs in the calculation process, rather in the communication network and the processors' ability to access memory. When ten million oxen need to agree on what direction to pull the plow in, that is not going to happen without some friction losses - and an ox on the right-hand side of the yoke cannot simply run all the way to the left-hand side in the middle of the work process to ask a question.

To answer some of the big scientific questions, such as on climate change, the human brain, in astrophysics or the earth sciences, or on whether fusion reactors can function as clean energy sources, we desperately need the enormous processing power of future supercomputers with modified algorithms and calculation methods. Every large-scale simulation task leads to new, fascinating questions. Thanks to the teamwork of computer scientists, mathematicians, and scientists from the applied sciences, millions of oxen are working at peak performance to push open the gates to new scientific territory.

Computer scientist Dirk Pflüger works at the Institute for Parallel and Distributed Systems of the University of Stuttgart and has been a member of the Junge Akademie *since 2015.*



A section of the large-scale structure in the Universe, which has a diameter of approximately one billion lightyears. The observational data are shown in blue, while the simulation is shown in red. Every point represents a galaxy.

PHOTO: V. SPRINGEL, C. S. FRENK AND S. D. M. WHITE, NATURE (LONDON) 440, 1137 (2006)

STUDYING THE MICROSCOPIC AND THE MACROSCOPIC WORLD

Scientists use supercomputers to better understand complex systems – such as in cosmology and molecular dynamics

TEXT BETTINA KELLER AND FABIAN SCHMIDT

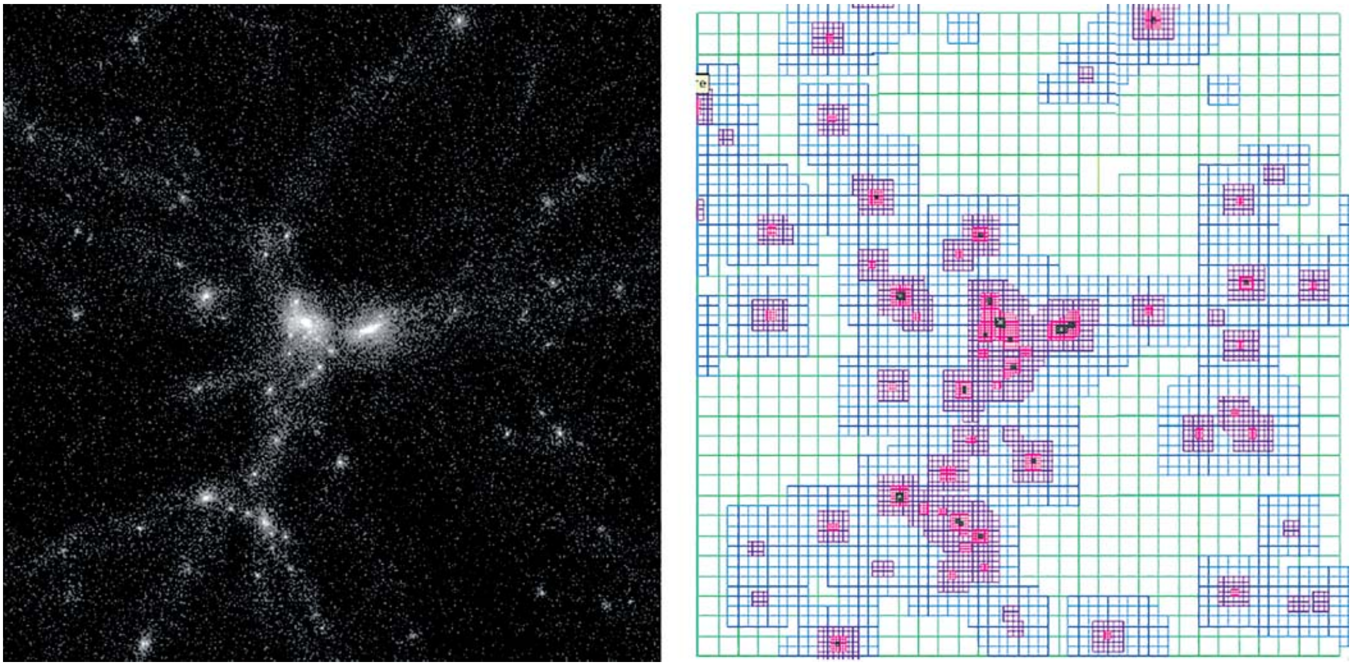
Hochleistungsrechner ('high performance computer') is the awkward German term for 'supercomputer', calculating machines that consist of hundreds of thousands or even millions of processors and sometimes fill entire halls. But has the international race for the largest and fastest computer long become an end in itself? What calculations are so complicated that you would need hundreds of thousands of processors at one time?

Cosmology and molecular dynamics are two disciplines in which supercomputers play a role in research. Although they are very different scientific fields, both use supercomputers to examine the behaviour of extremely complex systems by simulating interacting particles. Cosmology looks at particles of dark matter that interact via gravity, while molecular dynamics deals with atoms that interact via electromagnetic forces.

COSMOLOGY

The large-scale structure of the Universe (left-hand image) is one of the few tools that we can use to reconstruct its composition and evolution. By now, all facts point to a Universe that is dominated by 'dark' components. On the one hand, there is the dark matter that holds galaxies and galaxy clusters together and enabled their creation in the first place. On the other hand, there is the dark energy that is driving the accelerated expansion of the entire Universe. One of the main goals of modern cosmology is to discover more about the nature and the physical characteristics of dark matter and dark energy. The Universe began in an extremely hot, dense, and homogeneous state. The original fluctuations in the density and temperature of the Universe were smaller than a ten thousandth, which corresponds to waves 50 centimetres high in an ocean 5,000 metres deep. Under the influence of relentless gravity, these density fluctuations grew and after 14 billion years, they began to form the large-scale structure we can observe as well as the galaxies, stars, and planets within it.

In the ocean analogy, the height of the waves has since increased by a factor of a thousand. The waves now correspond to the



A two-dimensional cut-out of a cube-shaped simulation volume. On the left is the matter density in a cosmological simulation, and on the right an adaptive grid used for solving the equations (adaptive mesh refinement).

PHOTO: JEAN-MICHEL ALIMI, DEUS CONSORTIUM

size of waves near the coastline, where the height of the waves is nearly equal to the depth of the water. As 80 per cent of all matter consists of dark matter, we can imagine normal matter, i.e. galaxies and stars, as foam crests at the top of the waves. This means that we can trace the distribution of matter (the water) only indirectly (via the foam crests). To compare cosmological models with observations from astronomy, we need computer simulations that are able to depict the large-scale structure of the Universe. At the same time, the simulations need to have a sufficiently high resolution to allow us to roughly reconstruct the creation of individual galaxies. In these simulations, matter is represented by particles that interact with each other via gravity. The particles do not collide because they do not physically exist, but simply serve as a numerical aid.

One major obstacle lies in resolving the enormous range in sizes of structures, which is necessary because the volume of the simulation is at least one million times larger than the volume of a galaxy, while the matter within a simulated galaxy is compressed to ten thousand times the average matter density in the Universe. However, there is an important structural characteristic in the Universe that we can use to help us. The structure is almost fractal, which means that only a small part of the entire Universe collapses into very dense structures such as galaxies. By far the largest part of the Universe is taken up by large, low-density regions (so-called voids), which are ten thousand times more diffuse than galaxies. That is why our simulations require high resolution only in a small part of their volume. However, we cannot predict which regions in the simulated volume will need to be calculated at high resolution.

That is why our simulation codes use innovative techniques developed about 20 years ago. As part of the calculation, the codes decide independently and adaptively which regions will be calculated in high resolution and which ones will remain in low resolution. The two most important techniques are as follows.

First, the *tree algorithm,* used to organise particles into groups that function as point particles 'from a distance'. These groups have a hierarchical structure whereby one group contains multiple sub-groups, which in turn consist of numerous sub-sub-groups, etc. Only with this hierarchical structure can the simulation meet the enormous resolution requirements in dense regions.

Second, the *adaptive mesh refinement* technique, which uses a grid on which matter density is represented, and is employed to calculate gravity (image on left). Imagine the grid is like a digital photo, except that here brightness and colour are represented on a three-dimensional raster. The grid does not have the same resolution everywhere in the volume: voids are covered with just a rough raster, while the resolution is increased only for the area around galaxies. The code decides at every time step at which point the resolution needs to be increased or reduced. At those points, the simulation lays out high resolution grids that are spatially limited; like the groups in the tree algorithm, these grids have a hierarchical structure.

Both techniques have advantages and disadvantages and are used for different applications. Further, they are combined with a third technique, known as distributed calculation. Nowadays, most simulations are too large to be stored in the working memory of a single computer, even those with several hundred gigabytes worth of memory. Instead, modern codes can be run on several computers simultaneously, with each computer being allocated part of the volume. The computers communicate with each other about the interactions between the partial volumes via special protocols. This requires automated allocation among the computers so that each machine is working at close to full capacity.

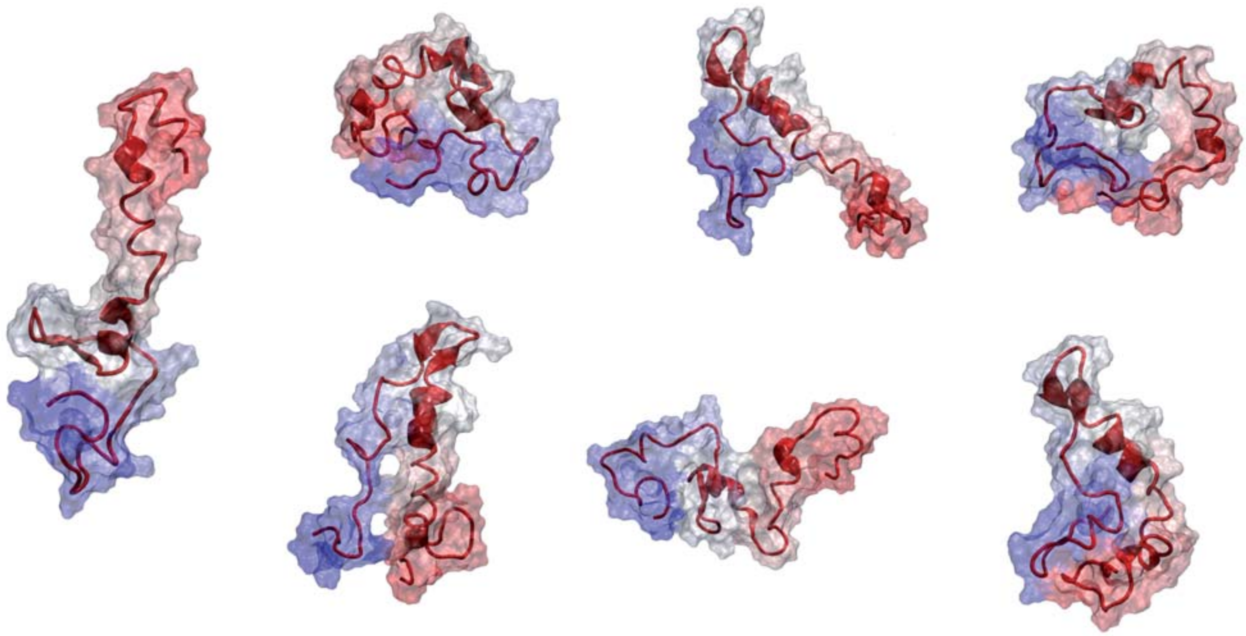
Computer simulations have thus become an indispensable tool in cosmology. However, simulations not only allow us to better understand nature at the largest scales, but also at the smallest, as in the case of molecular dynamics. One of the most interesting questions in this field is: how does life arise from the interaction of lifeless molecules?

MOLECULAR DYNAMICS

Ultimately, living organisms are made of atoms that link together to form particularly complex molecules, which in turn are in contact with each other and influence one another. These interactions lead to cell growth, metabolic processes, procreation, and interaction with the environment, or simply put: life. Molecules are by no means rigid entities, but rather continually change their three-dimensional form. In some cases, these molecules literally function like machines that fulfil tasks through the movement of their parts.

The figure on page 22 shows various three-dimensional forms, known as conformations, of a part of the protein p27. The backbone of the protein is shown in red; it looks like a ribbon taking on different forms. The surface of the molecule is shown as a transparent shell. The protein p27 plays an important role in regulating cell division, and its mode of action is based on its flexibility. It enables the protein to fit and attach itself to its counterpart, a cyclin-dependent kinase. In many tumour cells, p27 is either in short supply or is broken down so quickly that the tumour cells split far more rapidly than healthy cells. A range of experimental methods exists to study the conformational dynamics of a molecule. X-ray diffraction experiments deliver precise atomic images of individual conformations, but do not provide any information about the dynamics of the molecule. Spectroscopic experiments deliver average values for the conformational ensemble. Experiments on individual molecules allow us to ascertain the time evolution of a single distance within a molecule. However, it is almost impossible to reconstruct a complete picture of the conformational dynamics based only on experimental data. To do that, we need molecular dynamics simulations.

These simulations draw on findings about the interactions between the atoms in physical models. We model the atoms as point masses that carry a charge and can interact with each other. A new arrangement of the atoms in space corresponds to a new conformation. The movement of the atoms is determined by the laws of classical mechanics.



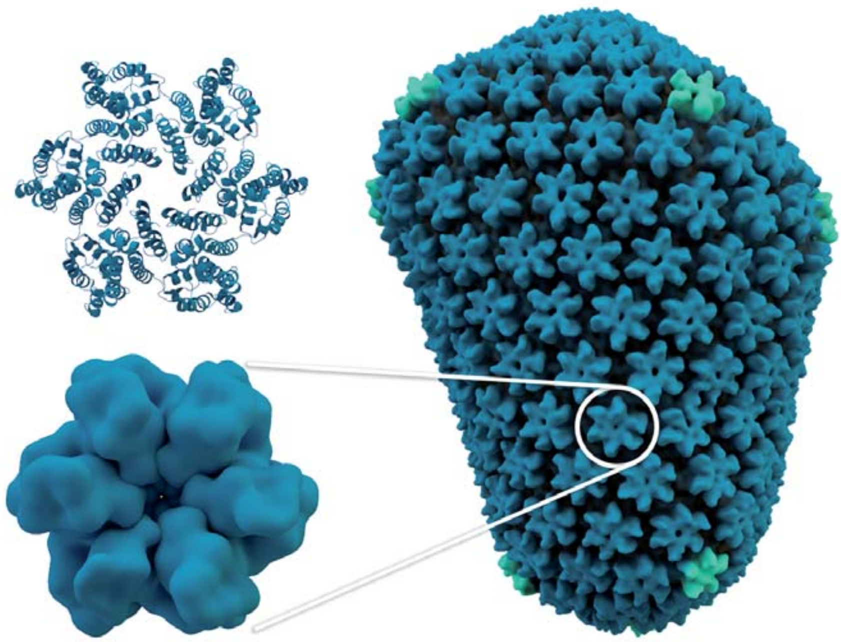
Different conformations of a (intrinsically unordered) protein.
The protein backbone is shown in red, while the protein surface is depicted as a transparent shell.

PHOTO: BETTINA KELLER

Based on the current conformation, the simulation program calculates the forces on each individual atom and moves the atoms along these forces for a short time step Δt. The new conformation is saved and the forces recalculated. Iterating this algorithm leads to a recording of the conformational dynamics – almost like a movie.

Why does such a seemingly simple algorithm require a supercomputer? The number of time steps is the critical factor here: the conformational dynamics of a large molecule takes place on a very broad spectrum of time scales. Two atoms oscillate along their bond vector in femtoseconds (10^{-15} s), while a large conformational change can take place within several milliseconds (10^{-3} s). The rapid bond vibrations define a time step of about two femtoseconds. Unfortunately, it is not possible to significantly increase this time step without a major negative impact on the precision of the simulation. As it is not possible to reduce the number of time steps, the time used to compute each time step has to be short. And that is where supercomputers come in. We simulated the conformational dynamics of the protein depicted above for 45 microseconds (10^{-6} s) on the HLRN-III supercomputer Konrad. This calculation required 22.5 billion time steps to be included. To get a better idea of that enormous number, imagine wanting to document the history of a place by taking a picture every single hour. At 22.5 billion pictures, the image series would reach back 2.5 million years, to a time when sabre-toothed tigers and mammoths still roamed the earth.

With a 'mere' 130,000 atoms, our simulation is a long way off from being the largest simulation. A milestone in molecular dynamics simulations is a study published in 2013 on the capsid of the HI virus (see above). Capsids are shells consisting of a large number of proteins through which viruses smuggle their DNA into the cell nucleus of the host organism. The shells are very stable outside of the cell nucleus, but as soon as they reach the nucleus, they dissolve into their elements and release



HIV capsid consisting of protein hexameres and pentameres. Molecular dynamics simulation show that the surface of the capsid is not rigid, but that the molecular building blocks slightly move against each other.

PHOTO: THOMAS SPLETTSTOESSER (WWW.SCISTYLE.COM)

the DNA. The basic building block of the capsid is the capsid protein (also known as p24; the similarity in the name with p27 is coincidental). Either six or five of these proteins latch on to each other to form hexons (blue) or pentons (turquoise), out of which the entire capsid is built.

The simulation conducted by the working group of Klaus Schulten on the Blue Water supercomputer at the University of Illinois at Urbana-Champaign contained a total of more than 1,300 proteins. Together with the surrounding water, the simulation box contained about 64 million atoms whose movement was simulated for a period of 100 nanoseconds, which corresponds to about 50 million time steps. The simulation showed that the hexameres and pentameres sometimes slightly shift within the capsid shell. The resulting cavities on the surface of the capsid could potentially serve as targets for the development of new HIV medicines.

Supercomputers are indispensable within the modern natural sciences. The two applications described here attempt to more fully understand the behaviour of extremely complex systems through the simulation of interacting particles. While the applications share underlying ideas, they differ in terms of the numerical challenges they present: in molecular dynamics, the problem lies in an enormous span of time scales, while in cosmology it lies in an enormous span of spatial scales. Both cases require the application of innovative simulation techniques that make full use of the performance capacity of today's supercomputers.

Bettina Keller and Fabian Schmidt joined the Junge Akademie *in 2016. Keller works at the Institute for Chemistry and Biochemistry at the Freie Universität Berlin. Schmidt is a researcher at the Max-Planck-Institute for Astrophysics in Garching.*

CAN CHOCOLATE MAKE YOU SMART?

We have all heard the saying that correlation does not imply causation, but novel mathematical methods can help to estimate causal structures from data without the use of experiments.

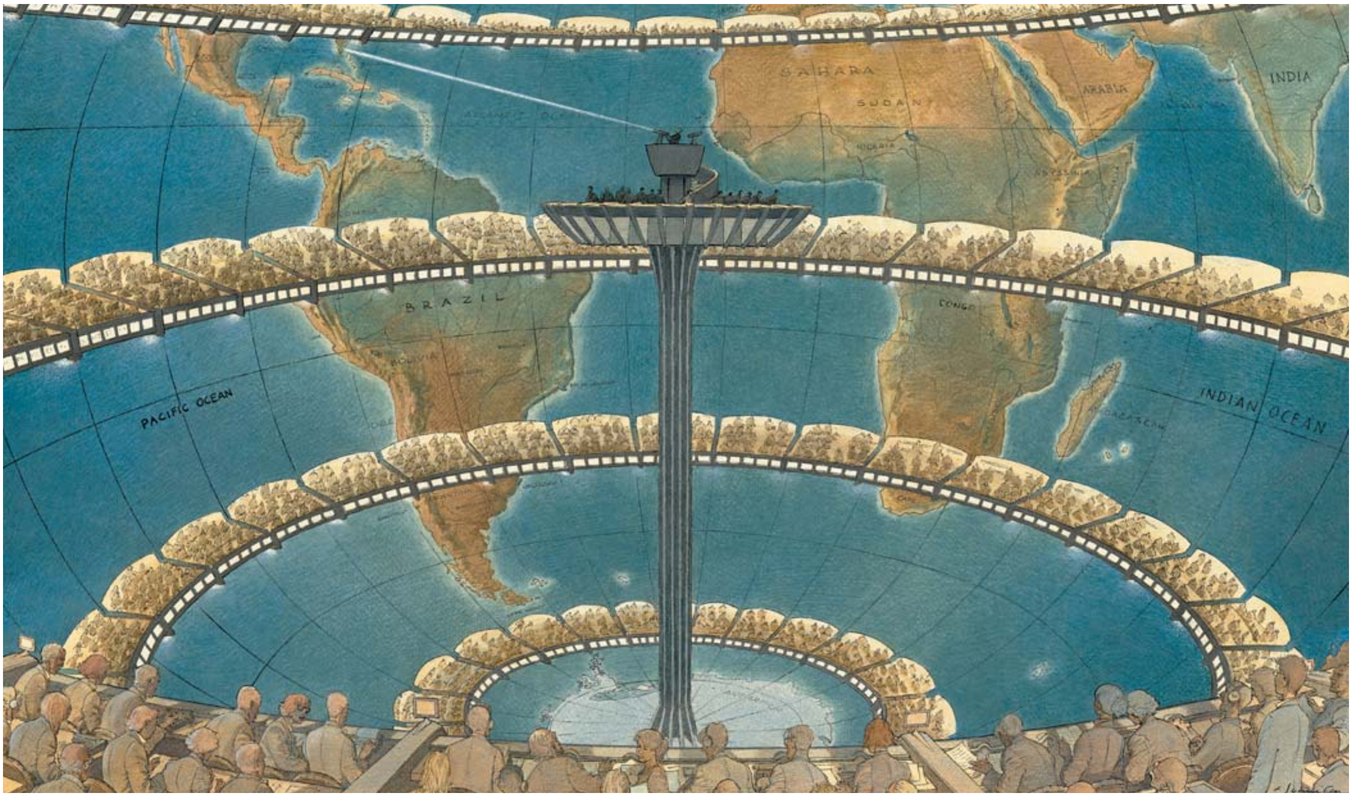
TEXT JONAS PETERS

Statistics show that countries with high levels of chocolate consumption have more Nobel Prize winners. Does this mean that consuming more chocolate increases your chances of winning a Nobel Prize? To answer this question, we would need to distribute chocolate in a few randomly selected countries and later assess whether the number of Nobel Prizes won by citizens of these countries had increased. While many students would no doubt welcome the introduction of a two-bars-of-chocolate-a-day policy, such an experiment is hardly feasible.

In other situations, interventions of this type fail due to ethical, physical or financial reasons. Many researchers believe that it is impossible to draw conclusions about causal links without the help of carefully implemented, randomised experiments. They argue that statistical links do not necessarily lead to conclusions about causal links - as encapsulated in the phrase 'correlation does not imply causation'. Current research projects on causal inference seek to disprove this notion. Researchers are developing methods that enable them to recognise causal relationships between simultaneously observed phenomena without active intervention by researchers in the system. These methods are based, for example, on the idea that real-life relations between variables are not arbitrarily complex. If that were the case, then Facebook would not be able to predict which stories will be of interest to users, Google would not know what we're looking for, and our smartphones would not understand our voice inputs.

This principle of simple relations can also be exploited for causal inference: if a model describing how Y is computed from X is simple, then in many cases the model describing how X is computed from Y must be particularly complex. This is somewhat surprising, but can be mathematically proven. We then propose the simpler model as the causal model. This means that in practice, we can limit ourselves to the simple models and see whether it is easier to explain data using a model from X to Y, from Y to X, or whether neither direction allows for a simple explanation. In the chocolate example, it is not surprising that the data do not suggest a simple causal link: chocolate consumption does not have causal influence on the number of Nobel Prize winners, nor does anyone who has just won a Nobel Prize suddenly begin to consume large amounts of chocolate. Instead, we expect an unobserved variable such as the economic power of a country to have an influence on both aspects - on chocolate consumption and the number of Nobel Prize winners.

Interesting scientific problems often deal with more than two variables. For example, researchers studying biological interaction networks attempt to predict the consequences of an intervention: what will happen if specific genes are deleted or certain proteins deactivated? Causal methods are of interest here as there are often far more possibilities for interventions than can ever be carried out in experiments. Based on the principle of the simple model described earlier, we would like to find out which causal structure yields the best data fit, that is, performs best in explaining the data. It is impossible, however, to test every structure, as the number of structures is simply too great - even when we exclude feedback and hidden variables. For two given variables X and Y, there are three possibilities (X causes Y; Y causes X; no causal link); for three variables X, Y, and Z, there are 25 possible causal structures; and once we're up to 13 variables,



François Schuiten illustrated Lewis Fry Richardson's idea for a 'forecast factory', in which thousands of people simultaneously solve differential equations in order to deliver a global weather forecast.

there are already 18,676,600,744,432,035,186,664,816,926,721 possibilities.

Little more than a hundred years ago, the mathematician, physicist and meteorologist Lewis Fry Richardson designed one of the first architectures for what are nowadays known as parallel calculations. Richardson imagined an enormous hall in which thousands of human 'computers' simultaneously solved differential equations on pressure or temperature for the small part of the world ascribed to him or her, as illustrated in the picture by François Schuiten.

Richardson was far ahead of his time with his idea, and later on, the largest computers in the world were indeed employed for weather forecasting for many years.

Richardson's idea also helps us to find the best (and therefore causal) model. An often-applied strategy consists of starting with a random causal structure and testing at every step whether it is possible to find an even better explanation for the collected data - for example, by changing the structure slightly through switching the causal relationship between two variables or discarding it entirely. All of these possible changes are reviewed simultaneously by the many processors of a supercomputer. This makes it possible to solve problems with not just 13, but with thousands of variables. The coming years will show to what extent such causal methods can help us to better understand real-life systems.

Richardson believed the benefit of parallel calculation lay in the calculation of large, deterministic systems. Today, parallelisation is an indispensable part of data processing (machine learning, data science). Companies such as Google and Facebook would not be able to process their enormous volumes of data without it, nor would the detection of causal structures be possible. We can therefore assume that parallel calculation will continue to play a major role in this field for many years to come. For all his foresight, Richardson certainly never expected that his idea would lay the groundwork for all these applications. And he would have been surprised, too, to learn that the tasks of the 'computers' would one day be carried out not by people but by electronic processors small enough to fit by the hundreds on a small graphics card.

Jonas Peters has been a member of the Junge Akademie *since 2016 and works in the Department of Mathematical Sciences at the University of Copenhagen.*

EXPLORING THE SKIES

Atmospheric physicists Bernadett Weinzierl and Leonhard Scheck explain why not even the best computers today are able to produce an exact weather forecast

INTERVIEW MIRIAM AKKERMANN

JAM: Leonhard, how would you describe your research?

Leonhard Scheck: My work focuses on using satellite images to improve weather forecasting. Every few minutes, numerous weather satellites transmit images of the earth that contain a great deal of data about clouds, air humidity, and temperature. A portion of this data is already being used and is incorporated into weather forecasting via a process known as data assimilation. This important step in weather forecasting requires complicated calculations on supercomputers and uses the results of the measurements to establish the current state of the atmosphere. The more precise the knowledge about the atmosphere, the better the forecasts. Satellite images using infrared wavelengths have proven to be particularly relevant here, as they provide information on air humidity and temperature for the entire globe. Satellite images using visible wavelengths also contain important information that is not included in the infrared images. These images show clouds and their characteristics, such as the dominant size of droplets, and whether the droplets consist of water or ice crystals. In contrast to the infrared images, it's not so easy to collect this information from the images, which is why they are currently not factored into weather forecasts. Right now, I'm using the data provided by the weather forecasting model to calculate synthetic satellite images. Once I've done that, I'll compare the synthetic images with the ones delivered by the satellites. The differences between the images enable me to conclude how the state of the atmosphere in the computer model needs to be modified to be closer to reality. The end goal is to improve weather forecasting for events such as thunderstorms.

JAM: Bernadett, what do you focus on in your research?

Bernadett Weinzierl: At the moment, my team and I are studying the influence of aerosol particles on the atmosphere and the climate. We are preparing the large-scale airplane measurement campaign A-LIFE that will take place above Cyprus in early 2017. Our aim is to obtain data at various heights, so we're optimising measuring instruments and installing them in a research airplane. We'll use the plane to fly into the atmosphere and study its different levels, such as the troposphere (located between zero and 12 kilometres above the earth's surface), which contains high concentrations of mineral dust and soot. The dust and soot come from the Sahara and make their way to us via big forest fires in the USA or Canada or from large metropolitan areas. After the Eyjafjallajökull volcano erupted in 2010, we measured how much volcano ash from Iceland was transported to Germany and at what height. Particle contamination in the atmosphere occurs as a result of both natural and human activity. We assume that about 20 to 40 per cent of the so-called optical thickness, which is a measure of the turbidity of the atmosphere through aerosol particles, has anthropogenic origins. In a changing climate, the emissions from natural aerosol particles could undergo dramatic transformation. But different studies have reached contradictory conclusions. For example, it's not clear whether in a warmer climate, the emissions of mineral dust would decrease or increase.

JAM: Could that also have an impact on weather forecasting?

THE ATMOSPHERIC PHYSICISTS

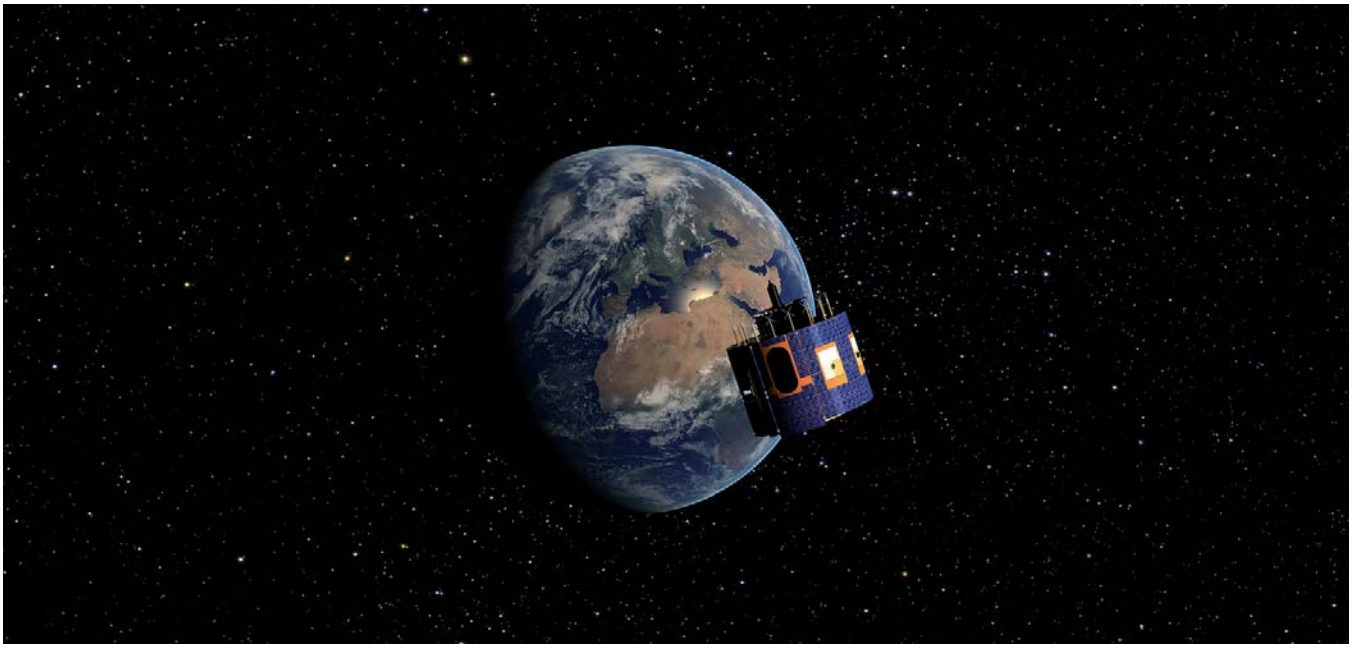
Leonhard Scheck is a researcher at the Hans-Ertel Centre for Weather Research at the Meteorological Institute Munich at the LMU Munich.

Bernadett Weinzierl joined the Junge Akademie *in 2014 and is Professor for Aerosol and Cluster Physics and director of Aerosol and Environmental Physics in the Faculty of Physics at the University of Vienna.*

Bernadett Weinzierl: Absolutely. When there are large amounts of Saharan dust floating above Vienna or Munich, for example, then the weather forecast usually is not accurate. One reason for that is that most of the forecast models do not take the effect of aerosol particles in the atmosphere into account. That's why it's important for us to measure aspects such as the size, form and chemical composition of the dust particles as well as the changes they undergo during transport and to incorporate that data into the weather forecast.

JAM: What do you do with the enormous amount of data that is available today?

Leonhard Scheck: Thanks to advances in data assimilation methods and the evolution of supercomputers, it is possible to process at least a part of this abundance of observational data and use it within weather forecasting. Some of the fastest supercomputers in the world are employed for this purpose, which pays off enormously: weather forecasting has markedly improved over the past few decades simply based on the assimilation of satellite observations. Together with improvements in the forecasting models, this has improved the accuracy of forecasts to the point where a five-day forecast today is on average as accurate as a three-day forecast was 20 years ago. Despite the improved supercomputers available now, it's still not possible to use all the data captured by the satellites. This is because advancements in the measuring instruments are leading to an increase in the flood of observational data. That's why, in the assimilation process, we try to limit ourselves to using only the data that has the biggest impact on improving the forecast. Some observations, such as the visible satellite images I mentioned before, are not assimilated for other reasons: it takes a lot of time and effort to interpret them and it would take too long using the traditional methods, even on the next generation of supercomputers. In this case, high performance is required in another area, namely in the development of far more efficient methods. This would enable us to process a much larger portion of the data flood in the future.



Scheck works with data from the EUMETSAT Meteosat Second Generation.

PHOTO: EUMETSAT

JAM: Does it still make sense to collect more data than is possible to use at this time?

Bernadett Weinzierl: Yes, because the continued development of analysis algorithms enables us to evaluate the collected data ever more quickly and comprehensively, and it's often the case that the analysis of data sets leads to new questions that can then be investigated using the additional data. Usually you begin a project with a concrete research question, consider which data you will need to answer the question, and then work with the collected data sets to answer the research question. In a well-planned project, you'll be able to evaluate most of the data. In a project conducted by the DFG research group SAMUM on Saharan dust, the data set was so good that the members of the group were able to publish more than 70 books and articles, and ten years later, we're still able to work with the data collected during that airplane experiment. Sometimes it's not possible to evaluate all the data because a new project is already set to begin.

JAM: How closely are research and practical application linked with one another?

Leonhard Scheck: The Hans Ertel Centre for Weather Research works closely together with the *Deutscher Wetterdienst* (German Weather Service). We conduct fundamental research in the field of data assimilation and develop methods to improve weather forecasting. Our goal is to make these methods operational for weather forecast services. There are still many fundamental questions that need to be answered when it comes to the assimilation of visible satellite images, but in a few years the process should be at a point where it can be used by weather services.

Bernadett Weinzierl: Many research developments occur at a time when it's not yet clear what practical application the discovery may have. Sometimes fundamental methods quickly find practical application. The 2010 eruption of Eyjafjallajökull in Iceland in 2010 was of great benefit to our fundamental research on Saharan dust and measurement methods, and we were therefore able to quickly provide information on aspects of the volcanic ash and how it would disperse. Volcanic ash is similar to Saharan dust in several aspects, such as a large particle size of between ten and 30 micrometres. To compare: a human hair has a diameter of 100 micrometres.

JAM: What are the limits of forecasting?

Leonhard Scheck: Forecasts about large-scale weather patterns can pretty accurately be made a week in advance. But when it comes to summer thunderstorms, it's difficult to say

Weinzierl often uses measurements taken by the DLR research airplane, the Dassault Falcon 20E.

where a storm will occur and how strong it will be, even just a few hours in advance. The smaller the scale of a weather event, the less easy it is to predict. The counter-example is that of climate simulations that deal with statistics on larger spatial and temporal scales, such as how frequently certain large-scale weather patterns occur and how high the average monthly temperature is. It's much easier to make predictions at that level, and it's even possible to calculate how the climate will change over the next few decades.

The reason why we cannot predict large-scale weather patterns any further than 14 days in advance is not due to the methods, but mainly due to nature: the equations that describe the atmosphere are chaotic. In a chaotic system, the smallest aberrations in the initial state can cause enormous changes in the final state. So if I make a prediction and at the beginning of the process there is an error in the temperature of even one degree, then it does not matter how good my forecasting model is. In the following two weeks, the weather will diverge from the forecast in an unforeseeable way. That is no fault of the meteorologists. At the Hans Ertel Centre for Weather Research, we look at how close we can get our weather forecasting models to the limit of predictability. To get closer to this boundary, we need, on the one hand, improved assimilation methods in order to make better use of more observations. On the other hand, we also need to consider that the models contain diverse simplifications. Without these simplifications, it would not be possible to calculate a forecast even with supercomputers. However, simplifications also lead to unavoidable errors that must be taken into account during data assimilation, and we need to find ways to reduce the magnitude of errors in the next generations of models.

Bernadett Weinzierl: I'm more concerned with the limits of measurability. We recently worked together with NASA on a project that examined what effect biofuels have on airplane emissions, in comparison with traditional jet fuels. To measure the changes in particle emissions in relation to the type of fuel, it's necessary to fly into the exhaust fumes of airplanes, which requires top performance from the flight crew. It means they have to fly less than a hundred metres behind another plane. Once the distance between two planes reaches several hundred metres, then the turbulence can become so strong that it becomes dangerous for the research airplane. With excellent planning of our measurement flights, we're able to reach our scientific goals while minimising the risks for the crew.

The interview was conducted by the musicologist Miriam Akkermann, who has been a member of the Junge Akademie *since 2015.*

COMMENTARY

Impact? Why young investigators should not be measured based on the number of their citations

TEXT TOBIAS J. ERB

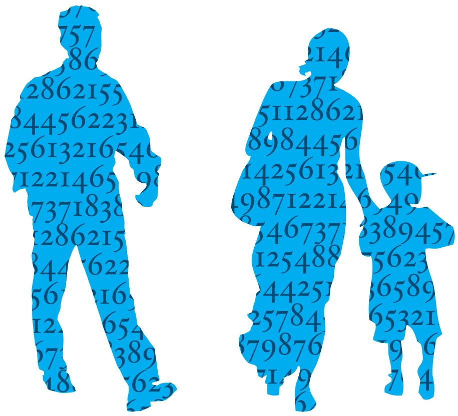
What is scientific top performance and how can it be quantified? Over the last few years, there have been numerous attempts, especially within the natural sciences, to objectively measure scientific performance. Publications in scientific journals, for example, are tagged with bibliometric identification numbers such as an *Impact Factor* or an *Eigenfactor.* Within this system, publications in top-tier journals are regarded as particularly valuable.

Scientists are increasingly being evaluated according to their *i10-index, Hirsch* or *h-index,* and their *g-index.* These numbers attempt to quantify the significance of researchers based on the number of their publications and citations. The latest arrival in this field is the *altmetric attention score,* which measures the influence of scientific works based on the attention they receive within the public and the media. Every newspaper article, every mention in a blog or a tweet, automatically increases the attention score by a certain number of points.

These various units of measurement all attempt to do the same thing in one way or another: they seek to use bibliometric parameters to derive the impact of a researcher or a researcher's work and thereby determine the value of a researcher. The algorithms, factors, indices, and scores are meant to be objective, but the end result is a number that we use in evaluations to compare, sort and rank researchers. But what is even more problematic is that these numbers, based on a researcher's completed works, are being used to predict the success and significance of the researcher's next projects. Most of these quantitative factors have only been introduced over the last decade (see table), and they are gaining in significance. My generation is the first to experience what it is like to have our careers be strictly evaluated according to these criteria, and we must adapt our behaviour accordingly. But is it right that our worth be measured only in these terms? Don't such measurements encourage us to pursue short-term success? And don't they pressure us to enter research fields that are conducive to rapidly producing published works with high impact?

The production of scientific knowledge is not a sprint. It takes time, sometimes even a great deal of time and trust. This is especially true in regard to entering new research fields and exploring new territory. It would therefore be a shame for a system that thrives on individuality, creativity, and curiosity about the unknown to shift to producing conformists who conduct research *for* rapid, measurable impact instead of research *with* long-term impact.

Significant scientific results have an impact, but the inverse is not necessarily true. Quantity and quality are not the same. As researchers embark on their careers, shouldn't their own vision be their main priority? I would wish that the scientific community would support emerging researchers based on their



new (and hopefully revolutionary) hypotheses instead of trying to evaluate previous achievements in a very short career on the basis of parameters that are not fit for purpose. Aren't innovative researchers more like adventurers than planners? If we already know what the outcome of an experiment will be, then is it still an expedition into the unknown? Can such research still generate leaps of understanding?

So how about creating a *uniqueness score,* an *innovation index* or a *non-conformity factor* for emerging researchers and their hypotheses? We could then use those measurements to evaluate researchers in terms of the future, long-term innovation gain or the unpredictability of their projects and ideas.

It's probably nothing but a beautiful dream to think that in the next few years we'll manage to change our culture of support and establish new performance indicators. But in our role as reviewers, we could remind ourselves during the next round of applications that this is an interesting scientific problem and a question worth pursuing before we start thinking about the impact of the candidate in question.

Tobias J. Erb joined the Junge Akademie *in 2013. He is a researcher at the Max-Planck-Institute for Terrestrial Microbiology and the Centre for Synthetic Microbiology in Marburg.*

THE MOST FAMOUS BIBLIOMETRIC INDICES

1955 | Impact Factor
(Garfield; Science 122:108-111)

2005 | h-index
(Hirsch; PNAS 102:16569-72)

2006 | g-index
(Egghe; Scientoetrics 69:131-152)

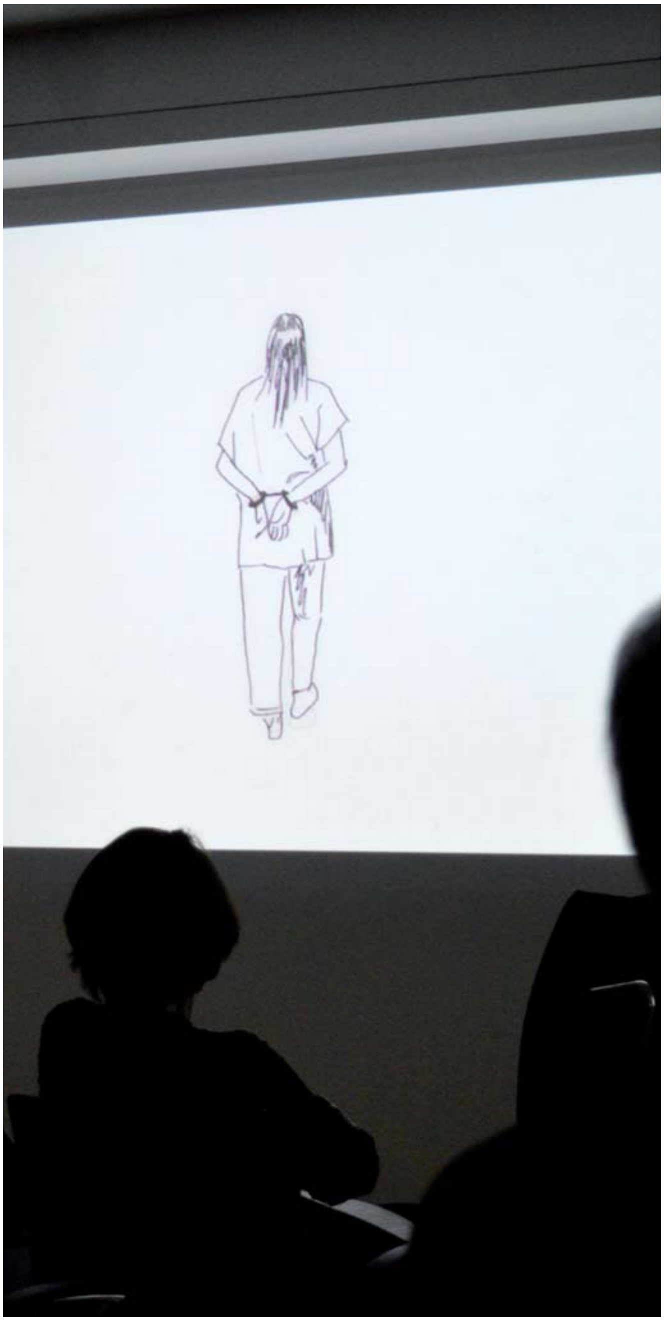
2008 | Eigenfactor
(Bergstrom, West, Wiseman; J Neurosci 28:11433-11434)

2009 | e-index
(Zhang; PLos ONE 4:e5429)

2010 | i10-index
(Google Scholar)

2010 | altmetrics
(Priem, Taraborelli, Groth & Neylon; http://altmetrics.org/manifesto)

2011 | Twimpact Factor
(Eysenbach JMIR 13:e123)



Scene from "Eye for an Eye" by Steve Bache, Mahyar Goudarzi and Louise Peter

RUNNING AS A METAPHOR

The 'be a better being' short film competition explores the constant human striving to be a better self

TEXT DEIDRE RATH

The interdisciplinary film forum that took place at the Deutsche Kinemathek in Berlin on 17 and 18 November 2016, took as its motto nothing less than to 'be a better being'. That title was reflected in diverse submissions whose topics ranged from individual self-improvement to the search for happiness to a new orientation of the social order. Of the 425 entries from 54 countries, 17 made it into the final round and were the subject of panel discussions between academics and film makers. The competition was a project of the *Junge Akademie* in conjunction with the short film festival interfilm berlin, the Film University Babelsberg, and filmArche, a self-organised film school. The project was led by *Junge Akademie* member Philipp Kanske as well as alumni Evelyn Runge and Magdalena Nowicka, conceived and coordinated by film maker Bobby Henzler, and made possible with support from the Commerzbank Foundation.

The festival began with the screening of a short film by American film maker Regan Avery, whose entry demonstrated how the digital world is opening up new possibilities to reflect on one's own self. The trend toward self-optimisation via tracking, i.e. the constant surveillance of one's own habits, is not new, but can now be pursued to a greater degree thanks to the latest technological innovations. Avery's film tells the story of a new fictional

Political scientist Carsten Q. Schneider discussing the subtle art of selection with (from left to right) film maker Helen Moltke-Leth, director Christoph Saber, and video artist Anna Henckel Donnersmark

Winner of the Audience Award: Helene Moltke-Leth received the award for her film "Running through Life". Jan-Hendrik Olbertz from the Commerzbank Foundation was on hand to present her with the award.

app named Enact that aims to free people from the burden of daily decision-making: from finding the right outfit for the day to organising leisure activities all the way to one's love life. Enact provides each user with a precise schedule of which activity is to be carried out at each point of the day, and enables users to become the person they've always wanted to be. Those who miss the spontaneity of daily life can choose to activate a coincidence generator – at least that is the cynical suggestion proposed in the film.

During the subsequent discussion, sociologist Hilke Brockmann, professor at Jacobs University in Bremen, confirmed that what seems like a joke at first glance is not all that far removed from reality. Brockmann pointed out that work is currently being done on a similar app entitled 'Happiness'. The aim of this app is not so much to spy on users' daily activities, but to study which conditions are necessary to ensure that people are happy. Brockmann argued that the constant striving for self-optimisation experienced today can in fact have the complete opposite effect on a person, and end in an addiction to permanent image cultivation. During the discussion, Brockmann also explained that the constant control of one's own image can be summarised as 'impression management', an explanatory model developed within social psychology, and she noted that a Facebook user who successfully portrays him- or herself as happy is often simply talented at self-portrayal.

Different panels dealt with the question of which social form enables its members to realise their goals. Is democracy really able to create the corresponding framework? Or could a capitalist system undermine democratic principles to such an extent that increasingly larger segments of the population are driven to the periphery and therefore no longer able to participate in fundamental social debates? We can also pose this question at the global level, because the chasm between poor and wealthy continues to grow, and goes beyond the borders of nation-states. In his entry 'The Learning Alliance', Pakistani film maker Umar Saeed accompanied three brothers of primary-school age who sort garbage in Lahore in order to afford their school fees. The boys want to play an active role in shaping their future and accept that the price required is that they labour under miserable conditions. For these boys, it is not the political system but rather only an education that will enable them to change their situation.

PHOTOS: DIE JUNGE AKADEMIE

Many film makers today focus on dystopian stories, which may be due to the instability of the current day and age. The desire for optimisation also includes evaluating humans based on their economic effectiveness. But what happens to those people who are less successful in this capacity?

This is precisely the question that German film maker Marc Bethke deals with in his film 'Mikelis'. With a hotel room (number 2020) as his backdrop, the aged protagonist Mikelis expounds upon the topic of the optimal society. He claims that his rather special program for population control has saved Europe from an over-aging society. Mikelis also argues that productivity is the cornerstone of a functioning, capitalist-oriented society. Those who are not productive are eliminated. As a result of this system, the protagonist himself dies at the end of the film.

In response, Carsten Q. Schneider of the Central European University in Hungary argued that while the film shows a radical and exaggerated position, the tendencies it highlights can already be observed in our societies today. In his research, Schneider, who is the founding director of the Centre for the Study of Imperfections in Democracies (DISC), ascertained that there are certain segments of the population whose members have significantly shorter lifespans as a result of hard labour than those members of better-off segments. This type of selection, Schneider argues, is subtler than that portrayed in the film, but is nonetheless incredibly effective.

The Audience Award of the competition went to 'Running through Life' by Danish film maker Helene Moltke-Leth. The film tells the story of Zoe Alpha, who goes for a night-time run through Copenhagen and starts to think about the daily social demands made of her. Here the ideal life is reflected in the protagonist's perfect good looks, rapid ascent of the career ladder, and high social status. And yet, Zoe has not managed to achieve personal happiness. Jury members Evelyn Runge and Philipp Kanske described how, '[t]he poetic language as well as the detailed visual and verbal depiction of the inner life of the character made this a clear winner for us. The film led us to ask ourselves whether running was a metaphor for humans' never-ending striving to be a better being.'

Project director Philipp Kanske conducts research at the Max-Planck-Institute for Cognitive and Neurosciences. Magdalena Nowicka is professor for Migration and Transnationalism at Humboldt-Universität zu Berlin. Evelyn Runge is currently a Fellow at the Martin Buber Society at The Hebrew University of Jerusalem in Israel.

Deirdre Rath is a student employee at the Junge Akademie.

„BE A BETTER BEING“

The short film competition “be a better being” brought together scientists, film makers, and the general public to engage in a joint discussion, thereby helping to build a bridge between academia and society. The organisers of “be a better being” and its predecessor “Europe: unlimited” find short films useful as a means of diagnosing the spirit of the current time, a function that sets short films apart from many research film formats, which have a tendency to depict natural science researchers at work. For a curated list of films, please visit betterbeing.info.

Workshop held as part of the Festival of Young Visionaries, organised by ZeitOnline "Z2X"

PHOTO: DIE JUNGE AKADEMIE

TAKING AN OUTSIDER'S VIEW

A conference of the Research Group 'Fascination' looks at the possibility of changing perspectives

TEXT MIRIAM AKKERMANN, ULRIKE ENDESFELDER, KATHARINA HEYDEN, PHILIPP KANSKE AND KAI WIEGANDT

'The Fascination of the Unknown' was once again the topic selected by the *Junge Akademie's* Research Group 'Fascination' for its third and latest conference, held in Leipzig on 28 and 29 October. Having covered the themes 'Space' (*JAM* No. 18) and 'Time' (*JAM* No. 21) at its previous conferences, this time the Research Group dealt with the theme of 'the Other'. With around 80 participants from Europe, Israel, and North America, the conference was the largest and in some regards the most unusual in the series.
A main goal of the conference was for participants to grasp the importance of a change in perspective as a fundamental prerequisite for a successful encounter with the Other. As we recognise that it is necessary to practice changing perspectives on a consistent basis, the following report has been put together from the perspective of one participant (Katharina Heyden), and from the perspective of the organisers (Miriam Akkermann, Ulrike Endesfelder, Philipp Kanske and Kai Wiegandt), with both parties unaware of the opinions of the other at the time of writing.

PHOTO: HANNAH SCHWOCHOW

OTHER PLACES

The Organisers:
The conference 'The Fascination with the Unknown: the Other' was not like other conferences. Here, researchers encountered artists, and practical exercises were combined with theoretical discussions. The spaces in Leipzig contributed to this diversity and openness. The practical exercises took place over four floors of the 'Haus Steinstraße – Verein für Kultur, Bildung & Kontakte', a house like Pippi Longstocking's Villa Villekulla in which no two rooms are alike: from the theatre stage in the attic to the office on the first floor, or from the room with a conference table to a yoga studio on the third floor. On the second day, the speakers gave their presentations in the same spot where Rammstein gave their first concert, years ago, standing on the large stage of 'naTo', an independently run cultural centre usually used for film screenings and concerts. The location will have played a role in the fact that 80 people turned up to listen – more than at other conferences and more diverse than many other conference audiences. There was room for everything on this stage: the expansive performances of Martina Hefter and Gal Naor, which included playing with sand, transporting children's toys, and dancing; the philosophy of Emmanuel Lévinas and the 'Mental Files Theory of Mind'. Even the paths between the different locations of the conference contributed to its success: the collective little march from the hotel to the Haus Steinstraße, during which the 'Others' of the conference first made contact with each other, to end up dancing, creating theatre, and meditating together just 30 minutes later.

The Participant:
The concept of 'leaving the comfort zone' ran like a red thread through the entire conference. It started with the rooms in which the participants gathered: the four workshops on Thursday led by artists took place in the 'Haus Steinstraße', an old, colourfully decorated villa in the centre of Leipzig that usually plays host to families and theatre makers. We ran into some of them in the stairwell during the breaks, including on Friday. A refreshingly unacademic choice of location. The program continued in a cinema. The 'naTo', a popular spot in the Leipzig cultural scene, provided an ideal space for the short films and performances on Friday evening. This space also posed some challenges for the researchers who were giving presentations on Saturday: where on this big stage should you place yourself? Where do you put the manuscript when there's no lectern? Answering these questions underscored the performance of different academic cultures – humanities scholars preferred to sit and read from a text, while natural scientists preferred to stand and speak freely.

THE EXPERIMENT

The Organisers:
Different methods exist within the sciences and the arts to approach the particular concept of the 'other'. What would happen if we invited scientists to try out an artistic method in a very practice-based workshop? Would it lead to new questions, new perspectives, even new findings? Would we understand the difference between our approaches? Would it lead to totally new perspectives with a concept of the "other" that we have previously not even been aware of? We invited artists from the fields of poetry/creative writing/dance/sign language, theatre, and meditation to the workshops. The goal was to enable participants to find a practical way to approach a concept: to go deep into one's own consciousness or into the thoughts of another, to imagine oneself in another person's shoes, to depict the other person, to regard oneself from an outsider's perspective. The evening's performance offered further inspiration, as did the two films, 'Vultures' (Joe McStravick) and 'When I Stop Looking' (Todd Herman), both entries in the 'be a better being' short film competition of the Junge Akademie. The performance and films turned into independent contributions in a language of their own. The next day, participants drew on these experiences and the resulting food for thought in the academic presentations. Which experiences and findings were comparable, which questions were similar and which approaches not as far apart as they seemed at first? This experiment was successful in getting participants to weave the lessons from the practical experiments into the academic discussion. It was particularly enjoyable to see how the seemingly obvious boundaries between the artistic and the scientific became blurred, and how all experiences were taken up in the lively exchange without any value judgements being made.

The Participant:
First the art, then the science – that was the concept of this conference. On the first day, the focus was on exploring different ways of approaching the 'other', with guidance from artists. During the day, the group engaged in literary, dance, theatrical, and meditative pursuits, and in the evening, took part in film screenings and live performances as audience members. The second day consisted of the academic symposium, with fascinating contributions from the fields of psychology and neuroscience on 'Theory of Mind' (Josef Perner), 'The potential of others' (Daniel Haun), 'Empathy and intergroup relations in the context of the Israel-Palestinian Conflict' (Simone Shamay-Tsoory), 'The social brain' (Philipp Kanske); from philosophy on 'Emotional states as a precondition to recognize one as an Other' (Eva Maria Engelen), 'Self and Others' (Kristina Musholt), 'Thinking the Other, thinking otherwise – Lévinas' conception of responsibility' (Eva Buddeberg), as well as from literary studies on 'Postcolonial Literatures and the Spectacle of Otherness'. For once, the artistic contributions served not just as part of the entertainment programme, but as a starting point for discussion! The reversal of the usual sequence for conferences (first the science, then the arts), meant that the arts and the practical experience gained on the first day attained their own significance within the scientific discourse. The scientific statements made in the discussions had to be proven against the experience of otherness gained in the workshops and performances of the previous day. Research needs not only to convince, but also to illuminate. What would it be like if the arts and the sciences did not exist as two separate blocks, but were even more tightly interwoven with one another by having art-based conference presentations alternating with science-based

presentations on the same day? The conference provided inspiration for trying out new scheduling possibilities at future events.

THE OTHERS

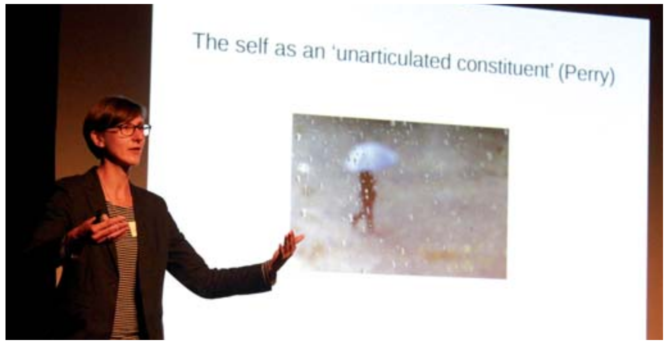
The Organisers:
In all, up to 80 other people took part in our experimental conference. Each person had a unique and different perspective, and most different professional backgrounds, with very few professions represented more than once. Here's a brief snapshot of conversations with various Others: *Can machines successfully imitate humans? One philosopher found an example that could be developed further, taken from a co-operative dance exercise in which the goal was to imitate others.* During the workshop, participants engaged in movement exercises that built on each other and amplified certain elements of movement. This concept was actively used during the scientific panel discussion: a participant took up a specific idea and developed it, opening up a new line of argumentation. It was an interesting idea to group the panellists' contributions by argumentation categories and opinions, thereby clarifying the ideas under discussion. *What occurred very often and was noticed by many: overall a greater degree of active participation among all attendees, more intense discussions, a more personal touch to conversations and less shyness about approaching others, even a longer duration of impressions and greater engagement with the contents of the conference.* The idea arose that reflective and empathy-focused workshops are generally a good initial concept for more successful conferences no matter the topic – even if not every topic can be translated into workshops the way we did it here with 'the Other'. *Different levels of communication: I understand what you're saying AND I can empathise with you. Body, gestures and spoken words!* Writing YOU (an additional workshop) as a practical means of conveying ethics? How does a better understanding and the conveying of ethics lead to more people choosing to donate organs, for example? *And we even briefly heard this: Impressive balance between scientific and creative exchange!*

The Participant:
'Leaving the comfort zone' is a phrase that you often overheard in the conversations during the breaks. Participants were intensely experiencing and discussing what effect the connection of experience, art, and reflection was having on the contents and the habitus of their scientific work. 'Empathy', the dominant theme of this conference, was particularly fruitful, as it was possible to observe how the development of arguments in scientific discussions is dependent on participants' ability to empathise with each other. In his keynote address, neuroscientist and German literature scholar Fritz Breithaupt highlighted the dark sides of empathy, thereby offering an important counterpoint to the general consensus of the conference presentations. The lively and controversial final discussion no doubt arose from the openness with which the participants engaged with each other. The discussion mainly focused on methodological questions of Othering within science and the political responsibility of science in regard to society. Is it legitimate to address the dark sides of empathy in a time that has been labelled a 'refugee crisis'? The organisers themselves repeatedly described the conference and their concept as an 'experiment'. This participant summarises with fascination: the experiment was a complete success – and provided inspiration to keep experimenting.

Miriam Akkermann joined the Junge Akademie *in 2015 and works in the Department for Digital and Audiovisual Media at the Universität Bayreuth.*
Ulrike Endesfelder is a researcher at the Max-Planck-Institute for Terrestrial Microbiology & LOEWE Center for Synthetic Microbiology in Marburg. She became a member of the Junge Akademie *in 2015.*
Katharina Heyden has been a member of the Junge Akademie *since 2012. She is Professor for Ancient History of Christianity and Interreligious Encounter at the Universität Bern.*
Philipp Kanske joined the Junge Akademie *in 2015. He is a researcher at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig.*
Kai Wiegandt joined the Junge Akademie *in 2014 and conducts research at the Institute for English Language and Literature at the Freie Universität Berlin.*

Further Reading:
theother2016.diejungeakademie.de

Performance by Gal Naor: Lights & Vessels Prologue

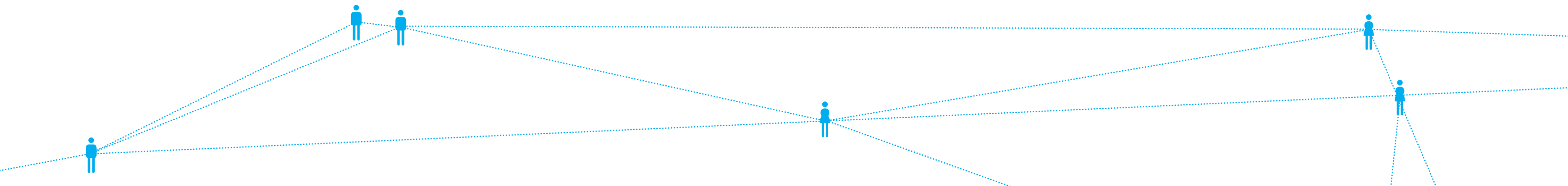


Kristina Musholt: Self and Others

'Translating the Self' Workshop by Gal Naor

Final Discussion

PHOTOS: HANNAH SCHWOCHOW, PHILIPP KANSKE



WORLDWIDE WEB

Now in its seventh year, the Global Young Academy faces new challenges around the world

TEXT BEATE WAGNER

Last December, when the Society for the German Language announced 'post-factual' as its 'Word of 2016', the office of the Global Young Academy (GYA) had already decided to focus on this term for its contribution to UNESCO's World Science Day. On 10 November, the United Nations Educational, Scientific and Cultural Organization, together with many universities and research institutions, celebrated World Science Day in order to draw attention to the importance of science for peace, development, and every individual human life on earth.

While preparing our campaign, the office team of the GYA had to take into account the shifts occurring within the major political and social discourses of the day. Whereas for years there had been increasing interest in scientific justifications for global political decisions, worldwide discussions recently began to undergo substantial changes, with the US presidential election only the latest event to have an impact. The result is that discussions are increasingly characterised by emotions instead of facts. When our team critically engaged with the term 'post-factual' at World Science Day, we were able to gain some media attention, but our campaign barely registered beyond the borders of the academic realm. As the last few months have seen an even more significant increase in the challenges facing this area of focus, GYA will further increase activities in its field of 'Science and Society'.

The GYA is a self-organised academy of young scientists from around the world. Our two hundred members hail from 54 countries and must provide proof of their academic excellence and social engagement when applying for membership. The average age of members at the time of entry into the GYA is 35, and most have completed their doctoral studies three to ten years prior to applying. Membership is limited to five years, after which time members join the ranks of alumni. The organisation of our alumni structure will be an important topic at our Annual General Meeting 2017, which will take place in Scotland in mid-May.

The GYA was founded in 2010 in response to an initiative of an international group of young scientists, and was supported by the Inter Academy Partnership, the National Academy of Sciences Leopoldina, and the Berlin-Brandenburg Academy of Sciences (BBAW). Since 2011, we have had an office in the BBAW building, supported by the Volkswagen Foundation and the Federal Ministry for Education and Research. The federal government plans to provide additional assistance to the Global Young Academy in the form of initial project financing at the National Academy of Sciences Leopoldina starting in 2017.

Political Consulting and Empirical Studies

Our members have defined three main areas of focus for the GYA: Science and Society, Research Environment and Science Education and Outreach.

In the field of Science and Society, members engage in publicity campaigns and most importantly in political consulting. We are particularly delighted that our members are regularly invited to present their findings in sessions of the Scientific Advisory Board of the United Nations Secretary-General. In 2016, they were invited by the Japanese government to present contributions during the G7 meeting of science ministers. The Joint Research Center of the EU also draws on and values the work of our members.

PHOTO: DUK/PHOTOTHEK

Our members in the Research Environment group are working on empirical studies on the topic of 'The Global State of Young Scientists' (GloSYS). A GYA pilot study from 2014 was investigating the challenges facing young scientists. All around the world, young scientists are confronted with precarious working conditions, which disproportionally affect female scientists. A GloSYS regional study is currently being concluded for countries in the ASEAN region and is being prepared for 14 African states. The results of the situation in ASEAN countries were presented in January 2017, and research on the situation in African countries will be completed in 2018. With this study, we not only document the current state of the situation, but also provide practical support. With our Science Leadership Programmes in Africa and Asia, the GYA is opening up opportunities for advancement for young scientists who are at the early and midway stages of their careers.

GYA member Sherien Elagroudy met UN General-Secretary Ban Ki-moon at the constitution of the scientific advisory council in Berlin in 2014.

Beyond that, our academy works to support teachers in many countries in delivering age-appropriate science instruction in schools. Our goal is to help young people around the world regard science as a viable career path in places where school instruction alone is not enough to make this seem an attractive option. The success of the Expedition Mundus game, developed by the GYA in collaboration with the Young Academy of the Netherlands, shows that play-based approaches can have a great impact in this regard.

Exchange in Africa, Asia and Around the World

In addition to project work, the GYA also supports exchanges between national young academies, particularly those based in Africa and Asia. In October 2016, for example, the GYA was a partner for the second meeting of young African academies in Mauritius, and in December helped to coordinate the first exchange among young Asian academies in Bangkok. To date, we remain active in both networks. The GYA plans to continue its cooperation in Africa in 2018 by collaborating with the Young Academy of Egypt. At the meeting in Bangkok, we laid the foundation for further collaboration in Asia, which will likely take place at the sub-regional level due to the size and diversity of Asian countries. Together with SAYAS, the National Young Academy of South Africa, we are organising a third global exchange among young scientists in South Africa in July 2017.

The GYA also works together with the well-connected young academies of Europe in relation to specific topics or events. In December 2015, we organised a workshop on the refugee crisis together with the Young Academy of the Netherlands. We are also open to collaborating with the Young Academy of Germany, particularly as our secretariat is located in Halle.

Beate Wagner took on the role of Managing Director of the Global Young Academy in July 2016. For more information, please visit: www.globalyoungacademy.net.

AWARDS, HONOURS AND FELLOWSHIPS

JESSICA BURGNER-KAHRS | TECHNICAL SCIENTIFIC PRIZE OF THE BERLIN-BRANDENBURG ACADEMY OF SCIENCES AND HUMANITIES

Computer scientist Jessica Burgner-Kahrs has been honoured with the Technical Scientific Prize of the Berlin-Brandenburg Academy of Sciences and Humanities for her outstanding work in the field of continuum robotics. Academy President Prof. Dr. Martin Grötschel bestowed the prize, endowed with 10,000 euros, on Burgner-Kahrs during Einstein Day celebrations.

LENA HENNINGSEN | LEOPOLDINA EARLY CAREER AWARD 2016

Sinologist Lena Henningsen has been awarded the Leopoldina Early Career Award 2016, sponsored by the Commerzbank Foundation and endowed with 30,000 euros. The National Academy of Sciences Leopoldina honoured Henningsen for her excellent research on contemporary Chinese culture and for her dedication to fostering intercultural dialogue and promoting a nuanced image of China.

GORDON KAMPE | SCHNEIDER-SCHOTT MUSIC PRIZE

The composer and musicologist Gordon Kampe has been awarded the Schneider-Schott Music Prize for 2016. The annual award, which is bestowed by turns on composers and musicians in a two-year cycle, is endowed with 15,000 euros. The award was conferred by Marianne Grosse, head of the Department of Culture of the City of Mainz, and the music publisher Peter Hanser-Strecker, in a ceremony at the Peter Cornelius Conservatory in Mainz.

WOLFRAM PERNICE | CONSOLIDATOR GRANT OF THE EUROPEAN RESEARCH COUNCIL

Physicist Wolfram Pernice has received support for his work from the European Research Council in the form of a 'Consolidator Grant'. With the help of the grant, worth close to two million euros, Pernice will carry out a research project within the field of optical quantum technology over the next few years. His goal is to develop optical chips designed to be used with individual light quanta ("light particles"). These chips are intended to enable the production of secure communications technologies as well as building blocks for the efficient simulation of complex systems.

BERNADETT WEINZIERL | NASA GROUP ACHIEVEMENT AWARD

Atmospheric physicist Bernadett Weinzierl received the NASA Group Achievement Award in the summer of 2016. Weinzierl was being honoured for her work within the context of the ACCESS-II-Measurement Campaign, which took place in California in May 2014 under NASA leadership. During the experiment, which involved a flight by the DLR research airplane 'Falcon', researchers analysed the emissions of jet engines that were by turns filled with traditional fuels and biofuels. The awards ceremony took place in Washington.

XIAOXIANG ZHU | VARIOUS AWARDS

Geoscientist Xiaoxiang Zhu was honoured with a number of awards in 2016, including the coveted Starting Grant of the European Research Council as well as the IEEE Interna-tional Geoscience and Remote Sensing 2016 Symposium Prize Paper Award. She also won the IEEE GRSS Image Analysis and Data Fusion Contest and received the IEEE GRSS Early Career Award and the DLR Science Award.

PUBLIKATIONEN 2016

FREMDENLIEBE – FREMDENANGST:
ZWEI AKADEMISCHE REDEN ZUR INTERRELIGIÖSEN BEGEGNUNG IN SPÄTANTIKE UND GEGENWART
(PHILOXENIA – XENOPHOBIA:
TWO ACADEMIC LECTURES ON INTER-RELIGIOUS ENCOUNTERS IN LATE ANTIQUITY AND THE PRESENT)

Can different religions share the same place of worship? How does inter-religious dialogue work? These under-researched questions are discussed here using examples from late antiquity: The examples highlight parallels and differences between the past and present in inter-religious encounters, such as the constancy of both the call to love strangers and the stoking of fear of others.

Author
Katharina Heyden

Publisher
TVZ Theologischer Verlag Zürich
March 2016

http://tinyurl.com/zapds4l

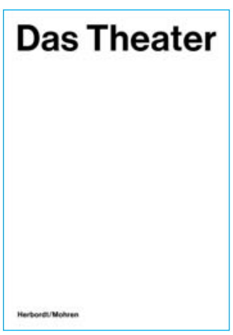
ZUM BRÜLLEN!
INTERDISZIPLINÄRES SYMPOSIUM ÜBER DAS LACHEN
(CRACKING UP!
INTERDISCIPLINARY SYMPOSIUM ON LAUGHTER)

This edited volume explores a range of topics including humour, wit, and irony. A recurring theme is the "danger" of laughter, as in the case of laughing at authorities. The contributions stem from philosophy and music education, literary and theatre studies, the legal sciences, and musicology, and even include a genuine literary text. Together, the contributions provide a multifaceted picture of laughter and its complex functions in many different contexts.

Editor
Gordon Kampe

Publisher
Olms, Essen
August 2016

http://int.olms.de/search/Detail.aspx?pr=2009147



DAS THEATER
(THE THEATRE)

What would happen if you staged an entire village as a piece of theatre? From October 2015 to June 2016, the artist duo Herbordt/Mohren invited audiences to participate in several performances in Michelbach an der Lücke. The action took place in empty spaces around the central village square, with the venues functioning as an archive, inn, cinema, museum, and a theatre. The book documents the project in photos, conversations, and film scripts. More details available at: *www.die-institution.org*

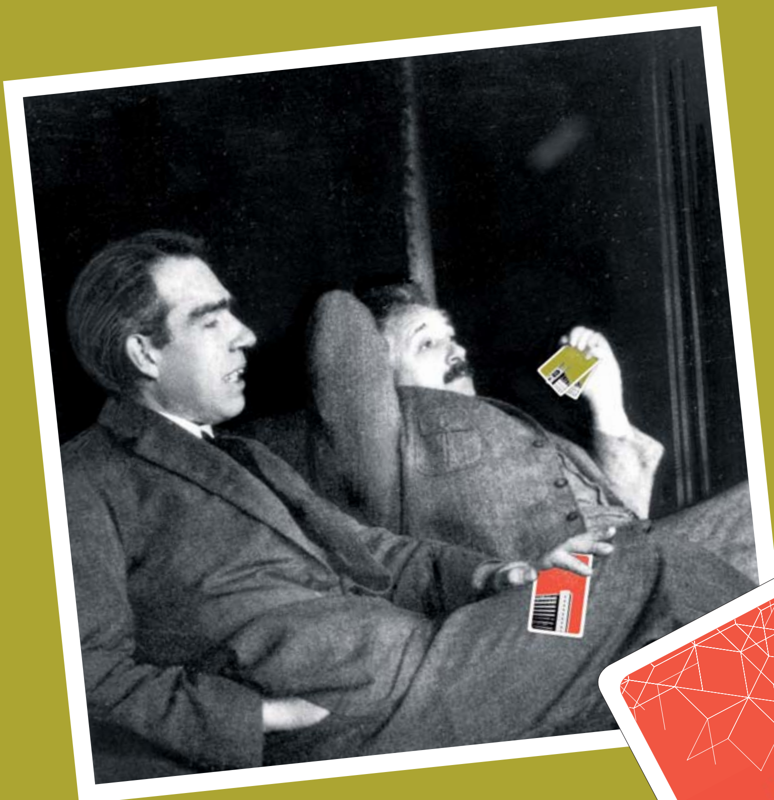
Editors
Bernhard Herbordt,
Melanie Mohren,

Publisher
Alexander Verlag Berlin
November 2016

https://www.alexander-verlag.com/programm/titel/392-Das_Theater.html

PEER REVIEW

AN ACADEMIC SIMULATION GAME



PEER REVIEW is an academic simulation game for four to six players. The game serves to hone the skills of emerging researchers, aid self-reflection among established researchers, and to provide the general public with a basic idea of how the academic system works.

- SIMPLE STEP-BY-STEP INSTRUCTIONS
- 37 TESTED EVALUATION STANDARDS
- 50 MERITS FOR ALL DISCIPLINES
- 192 CUTTING-EDGE RESEARCH TOPICS
- INTERDISCIPLINARY AND SOCIALLY RELEVANT

'The act of play is necessary to human life.'
Thomas (scholastic philosopher)

PHOTO: PAUL EHRENFEST/WIKIPEDIA

Copies of the game are available for pick-up from the office of the Junge Akademie, Room 223, or can be ordered via *office@diejungeakademie.de* to

EVENTS 2016/2017

2016 in review

7 July 2016
'Who is conducting cutting-edge research? Advantages and Disadvantages of the Excellence Initiative for Young Scientists'
Panel discussion at Humboldt-Universität
Berlin

14 July
'Career Opportunities for Scholars – Proposal for a Federal Professorship'
Panel discussion at the Berlin-Brandenburg Academy of Sciences and Humanities
Berlin

7 to 14 August
Summer Academy of the German Academic Scholarship Foundation
Kloster Roggenburg, Bavaria

18 September
'Border Phenomena'
Workshop of the Research Group 'Two Cultures'
Berlin

23/24 September
'Imaginary Food: Food in Contemporary Culture'
Workshop of the Research Group 'Popular Culture(s)'
Berlin

28 to 30 September
'Denaturalising Climate Change'
International Workshop of the Research Group 'Sustainability'
Oaxaca de Juárez, Mexico

6 to 8 October
Autumn Plenary Session
Bremen

8 to 15 October
Writing Workshop
Müritz

28/29 October
'The Fascination of the Unknown: the Other'
Conference of the Research Group 'Fascination'
Leipzig

17/18 November
'be a better being'
Short Film Festival and Awards Ceremony
Berlin

17 to 19 November
Symposium on 'Cultural Aspects of Migration in the Ruhr Area'
Duisburg

2016 in review

21 January 2017 **Evening Film Screening and Lecture on 'be a better being' as part of the DIALOGE 05 Exhibit**
Darmstadt

21 January 2017 **Sophie Charlotte Salon**
Berlin

28/29 January **Workshop of the Research Group 'Visualisation'**
Vienna

24 to 26 March **Spring Plenary Session**
Constance

April/May **Project 'Carefree I'**
Organised by the Research Group 'Art as Research'
Bremen

5/6 May **'Sweet Home' Symposium**
Essen

12 May **Symposium on '15 Years of the Junior Professorship'**
Berlin

Coming Up in 2017

9 June **Member and Alumni Evening**
Berlin

10 June **Summer Plenary Session and Celebration**
Berlin

11 June **Networking Event of the Young Academies in German-Speaking Regions**
Berlin

27 August to 3 September **Summer Academy**
Kloster Roggenburg, Bavaria

For the most up to date information on all events, please visit: www.diejungeakademie.de/veranstaltungen

CATCHING UP WITH …

Volker Springel, member of the *Junge Akademie* from 2006 to 2011

INTERVIEW DIRK LIESEMER

You were a member of the Research Group 'Quantum Theory' until 2011. What topics discussed in the group do you still think about today?
We talked about the interpretational difficulties of quantum physics. Even Einstein struggled with this. I'm not a quantum physicist, but I get the sense that these difficulties may even have increased since Einstein's time. For example, modern quantum field theories posit the existence of many additional spatial dimensions. Scientists used to think that the world is exactly the way we experience it for a reason that we have not yet understood. But according to string theory, another 10^{500} physically conceivable worlds could exist. I would say that the interpretation problems within quantum theory are reflected in the even more difficult comprehension of such quantum field theories.

You work in the field of computer-supported astrophysics. What do your computers need to be able to do?
The top performance of parallel supercomputers is currently about ten petaflops. That's 10^{16} arithmetic operations per second. It requires several megawatts of electricity and up to half a million processing cores connected to each other via high-speed communication networks. This set-up makes it possible to conduct calculations within a few weeks that would take a single computer tens of thousands of years to complete. The computers help us to better understand how stars and different types of galaxies formed. It basically allows us to trace the evolution of the universe from the Big Bang until today.

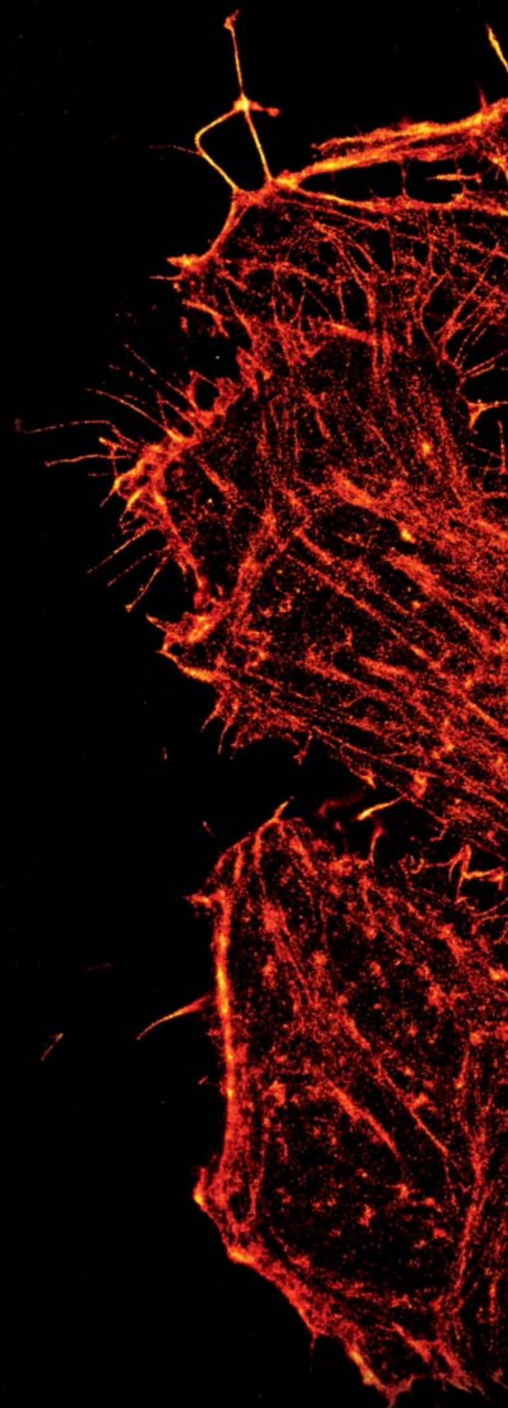
How do you do that?
We need to write a complex numerical algorithm that calculates the relevant physical laws as efficiently as possible. The problem is that the gravity within the universe has an impact on the dynamics of galaxies across great distances. For us, this means that we have to simulate a tightly interconnected system that cannot easily be split up into independent parts. That's why we spend a lot of time thinking about how to best divide up and

MEET VOLKER SPRINGEL

Astrophysicist Volker Springel leads the Research Group 'Theoretical Physics' at the Heidelberg Institute for Theoretical Studies. He also teaches in his role as professor at Heidelberg University and is a member of the Interdisciplinary Center for Scientific Computer at the university.

allocate the calculations so that they run effectively and precisely in parallel. We end up with programming code that consists of hundreds of thousands of lines, and it's the communication routines in particular that require a lot of effort. Every mistake causes one of the computers to crash.

What is the current state of your research?
I examine the effect of supermassive black holes on galaxies. Although these gravity traps are tiny, they can have a major impact on giant stellar systems. It's possible that supermassive black holes are the reason why galaxies can't grow beyond a certain size. There is quite a bit of evidence for this from observational astronomy. My goal is to prove that the energy released by black holes can efficiently couple into a galaxy. This makes it impossible for new stars to form, and hence the galaxy ages and 'dies'. It is fascinating: a supermassive black hole is capable of regulating a system that is several million times larger and ten thousand times more massive than itself.



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