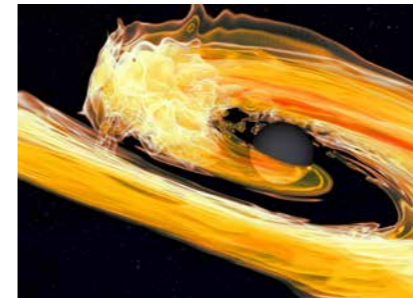


Ant Psychology: Tiny Heads, Complex Thoughts | Science and Society in Crisis Mode: Pause, Reflect, Respond | Final Report of the Pandemic Commission: Learning for a Better Preparedness | Autonomous Driving: Safe, Comfortable, Dynamic | Neutron Stars: When There's a Bang in the Universe | Film Industry: A Star is Born from Marketing



Cover: R. Cutura / K. Angerbauer / F. Heyen / N. Hube / M. Sedlmair / SFB-TRR 161

What looks like a patchwork project is the artistic visualisation of data sets using various methods of dimension reduction, created within the CRC/TRR "Quantitative Methods for Visual Computing".



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Katja Becker

# Pause, Reflect, Respond

*The current resurgence of anti-democratic thinking and uninhibited anti-Semitism at the heart of German society calls for a resolute response from the research community, as derives clearly from our role in a democratic society and our historical responsibility. Scientists and scholars have a particularly important task to perform in supporting democracy and open-mindedness.*

When the DFG's Interdisciplinary Commission for Pandemic Research recently presented its final report – as featured elsewhere in this magazine (see pages 4–7) – the focus was once again very specifically on one question which previously had not just been of particular interest to the Commission itself but which had also set the tone for the DFG's response to the coronavirus pandemic in general.

It is the question of preparedness: what can we learn from this crisis that will ensure we are even better prepared to tackle the next one?

The next pandemic has yet to materialise, but this is certainly not something that should lull anybody into a false sense of security. Other crises have long since arrived, dominating our thinking and action in such swift succession and with such an overbearing presence that the term “crisis mode” has become the second buzzword of the day, alongside the notion of a “watershed era” or “turning point” in history.

All these crises have at least one thing in common: they were always familiar to us, especially in Germany, as historical phenomena, yet we thought they had been either overcome, brought under control, or kept in check, even as they potentially slumbered beneath the surface. As a result, our astonishment, bewilderment and horror at their renewed and unbridled outburst was all the greater. This was certainly the case with the Russian attack on Ukraine. There have indeed been cases of military aggression in the middle of Europe in recent decades. But a war waged with such brutality, claiming the lives of tens of thousands, and with apparently no end in sight even after two years?

The same applies to the critical developments unfolding at the heart of German society. Anti-democratic thinking and anti-Semitism never completely disappeared, even in the post-war history of our country, which was initially separated in two for a long period of time before being reunited. But the idea that an anti-democratic attitude is now starting to take root in increasingly large sections of the population, threatening to achieve success in the political arena and even giving rise to fantasies of remigration, while anti-Jewish sentiment is showing its face unabashedly in attacks on Jewish citizens in the street, and also in lecture theatres?

The question has rightly been raised in recent times as to whether and to what extent we could and should have been better prepared to tackle these crises. This debate is still in its infancy, of course: the research community can and must make its own contribution here, and not least engage in self-critical reflection.

Yet another question is currently more pressing – namely that of preparedness: what and how can we learn from these crises as we look ahead to the future?

One answer is clear at least: just like the newly unleashed war in Europe, the current resurgence of anti-democratic thinking and anti-Semitism in Germany calls for a serious pause, intense reflection and a decisive response – and that means on the part of the research community and a research organisation such as the DFG, too.

In line with this maxim, we suspended all our institutional German-Russian research links two years ago. The guiding principle here was clear: Russia's invasion of Ukraine violated – and continues to violate – both international law and the international peace order, as well as the underlying values of research and research cooperation which seek to act as pillars of international understanding.



Illustration: DFG/Unkel

We must show the same determination in taking a stance now. Once again, the guiding principle is clear: anti-democratic and anti-Semitic slogans and actions are attacks on the foundations of our democracy and on the cosmopolitanism of our modern society. And they are attacks on the foundations of science and the humanities itself, which is protected and promoted in Germany in an exemplary manner – not least when compared to other countries – by the freedom of research guaranteed under the Basic Law, and which also seeks to contribute significantly to democratic discourse and to cosmopolitanism in our society, which it does very successfully.

In addition to this role in a democratic society, we also have a historical responsibility to bear: as an organisation whose predecessor was ominously implicated in the National Socialist terror regime, it is particularly vital for us to speak out today.

On this basis, we also unambiguously reject any anti-democratic and anti-Semitic tendencies in society as well as in academia and its institutions. On this basis, we have also taken a clear stand on numerous occasions in recent weeks and months in favour of democracy and cosmopolitanism and against anti-Semitism, racism and inhumane slogans and actions – at numerous public appearances as well as within the Alliance of Science Organisations in Germany, and also jointly with companies, associations and social actors in

the campaign #Zusammenland initiated by several major publishing houses (a motif from this campaign is to be seen on the back cover this issue of *german research*). We will continue to pursue such action with resolution and determination.

Finally, we will seek to expand our dialogue with society in the coming weeks and months on the same basis – together with the Berlin-Brandenburg Academy of Sciences and Humanities, the Union of the German Academies of Sciences and Humanities and the German Rectors' Conference. In a number of cities, researchers will be meeting citizens in person to engage in dialogue on science-related topics relevant to politics and society. This dialogue is very important to everyone involved, not least to me personally: after all, it is by entering into this kind of conversation that the particular strength of science and the humanities can be revealed, at the same time giving it a key responsibility: based on evidence and open discourse, they provide the knowledge that is the most effective remedy for fake news and conspiracy theories. At the same time, this knowledge paves the way for society to tackle the multiple global challenges of the present and future.

Professor Dr. Katja Becker  
1st President of the DFG.

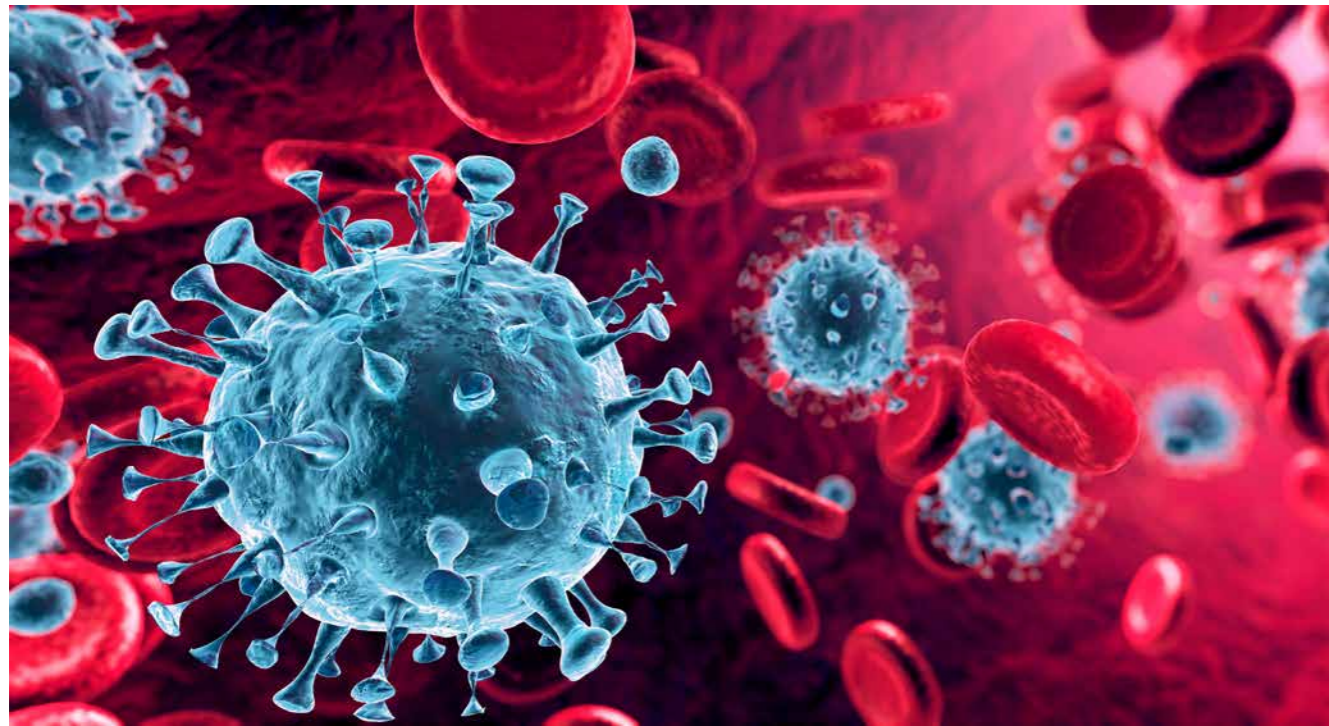


Illustration: Adobe Stock/Taverni

## Learning From the Pandemic to Ensure Better Preparedness

*The DFG's Interdisciplinary Commission for Pandemic Research has presented its final report: emphasising the importance of an interdisciplinary approach, it says that there is a need for much more research, while also advocating science-driven reappraisal and advisory structures.*

In tackling the coronavirus pandemic in Germany, science, politics and society benefited considerably from interdisciplinary research approaches and studies. Yet now that the acute pandemic phase is over, there remains a need for much more research to be done to pursue numerous questions. And if we are to be even better prepared for future crises, we urgently need to carry out a systematic and science-driven reappraisal of the pandemic and the measures adopted, also taking a critical view of the role of science itself.

These are three of the key conclusions drawn by the DFG's Interdisciplinary Commission for Pandemic Research after three and a half years of work from mid-2020 to the end of 2023. The Commission's final report was published at the end of March, having previously been presented to the DFG's Executive Committee, Senate and Joint Committee.

"The report underlines the significant contribution of free and knowledge-driven research to containing the pandemic," emphasises Commission Chair DFG President Professor Dr. Katja Becker in the

foreword. "The positive response to the Commission's work," Becker continues, "provides an opportunity to reflect on possible ways in which society and policymakers can continue to benefit from the wide-ranging expertise of the German research landscape and its organisations in the future. The experience gained by the DFG with this particular Commission could feed into such considerations."

When presenting the report to the DFG statutory bodies, Becker expressed her conviction that "transparent and interdisciplinary

scientific advisory structures are needed in Germany on a permanent basis and independently of crises so as to further deepen the trust between society, politics and science". According to the DFG President, however, such networks must be established and maintained on an ongoing basis before any upcoming crisis so that the potential of science is able to underpin existing structures in the event of an actual crisis occurring, in support of those institutions which are legally responsible for crisis response.

Established by the DFG in May 2020 as a deliberate addition to the numerous research and networking activities that swiftly emerged in Germany after the outbreak of the

coronavirus pandemic, there were two aspects of the Pandemic Commission that set it apart from other bodies. Firstly, and unlike most expert panels, it worked independently of any direct political advisory context. Secondly, and most importantly, it brought together the expertise of all the disciplines required to address pressing scientific issues, incorporating mathematical, scientific, technical, legal, social, psychological and historical aspects in addition to the medical and epidemiological perspective. In the report and also in the Commission members' personal retrospective comments, it is this enormous interdisciplinary breadth that is seen as a particular strength and

extremely beneficial (*see the personal retrospective comments on this page and page 7*).

More than 60 pages long and containing numerous references to other in-depth sources and materials, the report initially focuses on the major issues and areas of activity addressed at a total of 26 meetings by the Commission chaired by the DFG President, starting out with 18 members and later being expanded to 21 members. With the exception of the final meeting, all meetings were held virtually.

One focus of the Commission's work was the monitoring, coordination and support of coronavirus research projects, whether in ongoing DFG projects, in what was the DFG's

## Broad Expertise, Unbiased View

*Different from the rest: members' personal retrospective comments on the Pandemic Commission.*



Illustration: private

*I have very positive personal memories of the Pandemic Commission because it brought together so much expertise from a wide range of specialist areas, enabling sometimes controversial but always respectful, open and yet focused discussion of mostly complex problems – and also because*

*it enabled people to meet regularly, albeit virtually, during what was a very unusual time.*

**Simone Sommer, Biology, University of Ulm**

*The difference between the Pandemic Commission and other bodies was the impartiality of the discussion. Unlike many a politically motivated discussion that I experienced elsewhere, debate in the Pandemic Commission was always open-ended and focussed on the matter in hand. That is not something to be taken for granted, especially in a situation where we were working with un-*



Illustration: ammalacque

*certain data and in uncertain circumstances: it was only possible due to the Commission's particular membership, with people who were primarily motivated scientifically and not politically. We really did want to help and not take advantage of the pandemic to assert vested interests.*

**Michael Meyer-Hermann, Physics and Mathematics, Helmholtz Centre for Infection Research, Braunschweig**

*The Pandemic Commission not only succeeded in developing needs-based funding, it also enabled open-ended and very constructive dialogue that was highly productive and initiated crucial developments. We can only be grateful to the DFG for enabling swift action to be taken and also for demonstrating that self-organisation can function well in the research system in times of crisis, too, thereby making a vital contribution to the prevention and handling of crises.*

**Cordula Artelt, Educational Research, Leibniz Institute for Educational Trajectories and University of Bamberg**



Illustration: Thomas Riese

largest interdisciplinary call for proposals up to that time – launched in March 2020 – for research into epidemics and pandemics, or in connection with the DFG’s new “COVID-19 Focus Funding” pro-

gramme aimed at addressing acute research gaps at short notice. All in all the Commission was involved in funding more than 150 research projects, for which funds of more than €45 million were approved.

Other focal points and key concerns of the Commission and its members were research networking and the communication of its own work to the media and the public, both of which were addressed in a

## Engaged in Animated Dialogue

*Subject-specific networking and public dialogue – two of the Commission’s key concerns.*

When on 15 November 2021 the spotlights flashed on in the Norbert Elias Hall of the DFG Head Office in Bonn – which had been converted into a recording studio at short notice – camerapersons and presenters wearing protective masks moved into position and a highly sophisticated video conferencing system was booted up on numerous monitors around the world: all this demonstrated both the restrictions that the coronavirus pandemic had imposed on meetings of all kinds in this first lockdown autumn and, to an even greater degree, the huge digitalisation surge that it had triggered within such a short space of time.

The DFG and its Commission for Pandemic Research made the most of this to organise what was probably the largest networking conference on coronavirus research up to that time (*picture, right*): along with numerous guests from the world of research, researchers representing more than 100 DFG-funded projects – many of them involving international partners – followed the keynotes and discussions at the digital event, exchanged ideas in forums, established new contacts and intensified existing ones.

Even at this early stage, the joint focus was on possible lessons to be learnt from the pandemic for the future. Or as the title of the conference put it: “Preparedness for Future Pandemics from a Global Perspective”.

Just as was happening here on a broad scale, professional networking in numerous smaller formats had been a key focus of the Pandemic Commission’s work from the outset. This same objective – the reason the Commission itself was formed and indeed its distinguishing feature – was likewise pursued by research roundtables organised by the Commission, meetings with other research organisations, associations and policymakers, as well as the involvement



Illustration: DFG/Jenny Otto

of Commission members in numerous discussion panels and events organised by other stakeholders.

No less important to the Commission from the outset was communicating its work to the world beyond science and engaging in dialogue with the media and the public at large. It certainly showed a good sense of timing: at the end of January 2021, right at the start of the first nationwide vaccination campaign against the coronavirus, a dossier was published in the FAZ in which Commission members presented a collection of scientific evidence on the benefits and safety of a COVID-19 vaccination to a non-expert readership. The programmatic title of this widely read article: “Know more – make informed decisions!”

The Commission also promptly addressed current and controversial public and political discussions by issuing statements on the spread of Sars-Cov-2 viruses through aerosols and the use of health data for the purpose of coronavirus research and control.

The Commission’s in-depth communication work was rounded off with numerous articles and interviews by Commission members in print and audiovisual media, and also in the DFG magazines *forschung* und *german research*. **fine**



Illustration: U Paderborn

*I was particularly impressed by the constructive and intriguing interdisciplinary dialogue. This illustrated impressively what science and scholarship are able to achieve when they join forces in providing support for decisions relating to a specific major challenge, and also how it is possible to deal with the fact that an approach of this kind is fundamentally at odds with the scientific method, which is normally thorough and therefore slow-moving. In my view, some of the discussions were groundbreaking, too,*

*such as how to deal with provisional results and what it means to have a culture of error, both in science and in the public domain.*

**Caren Sureth-Sloane, Business Administration, University of Paderborn**

*For me, being on the DFG Commission was a special experience since it was very interdisciplinary in its membership, so I was able to gain a very differentiated, complex impression of the situation as the crisis unfolded. That helped me a lot in terms of assessing the progress of the pandemic from my own disciplinary perspective as a historian.*



Illustration: U Heidelberg

**Karen Nolte, History of Medicine, University of Heidelberg**

wide variety of formats (*see article opposite*).

In another section of its report, the Commission reflects on recurring cross-cutting issues that typified its own work and at the same time posed key challenges facing the research community during the coronavirus pandemic. These included the significant demand for interdisciplinary approaches and studies as well as the problems associated with research data and data links – something that is especially marked in Germany as compared to other countries. Key cross-cutting issues with regard to the research system and work process included the publication culture and research productivity as well as questions of translation, implementation and knowledge transfer. In terms of science and health communication as well as policy advice, the focus was also regularly on topics that went beyond the scientific context in the narrower sense.

In the concluding section of its report, the Commission addresses a number of issues that it still considers to be pressing after the end of the acute phase of the coronavirus pandemic and now that its own

work is complete. Here again, one key question is how society can be even better prepared to cope with future pandemics and crises of a similar nature.

The 21 Commission experts start by acknowledging that there remains a need for much research to be done in numerous fields, and they consider it particularly important to forge stronger links between basic research and research into public health. They also believe that much too little research has been done to date into the long-term consequences of COVID infections: here, says the report, there is a need for long-term, integrative cohort studies as well as multidisciplinary research approaches in order to be able to take account of the broader social and economic impact that goes beyond the long-term biomedical consequences. The Commission also sees a need for further research to be conducted into the long-term ecological consequences and damage caused by the pandemic, including that inflicted on the environment and animals, as well as investigation of the general relationship between biodiversity and human health in the light of the pandemic. Finally, the

report identifies an urgent need for action in implementation research and in particular in the translation of scientific findings into specific health-related measures.

The Commission concludes its report with an explicit plea for a systematic and science-driven reappraisal of the pandemic and the measures imposed, as well as a review of the role of science in the pandemic, saying that such a reappraisal is essential in order to be better prepared for future pandemics, potentially providing key insights for the revision of the Infection Protection Act and with regard to structural changes in health-related public institutions. The Commission is also in favour of a comprehensive historical reappraisal and contextualisation of the coronavirus pandemic – something which could likewise contribute considerably to the question of preparedness.



The final report can be found on the DFG website at: [www.dfg.de/resource/blob/329854/f11885dc7fbe1ed0f0d99f58723ade5a/abschlussbericht-dfg-pandemiekommision-data.pdf](http://www.dfg.de/resource/blob/329854/f11885dc7fbe1ed0f0d99f58723ade5a/abschlussbericht-dfg-pandemiekommision-data.pdf) (only in German).



## Migration as a “Trigger Point”?

In questions of migration, a sense of conditional inclusivity prevails in German mainstream society. Even though opinions on the issue are less black and white than often suggested, it remains riddled with conflict.

By Steffen Mau, Thomas Lux and Linus Westheuser

Migration is seen by many as *the* most divisive issue of contemporary societies, pitting champions of a “culture of welcome”, who regard immigration not only as economically necessary but also as culturally enriching, against a sizable minority who argue in favour of a reduction or even a complete stop of arrivals.

Among the population at large, both camps are approximately of the same size. This is seen, for instance,

in a poll we conducted on the most polarised of all migration issues, the hotly debated question of an upper limit on refugee uptake, particularly of those coming from Arab and African countries: 23 percent of Germans support such a cap, while 20 percent are opposed. This represents a clear and comparatively polarized line of conflict which is mirrored in the oppositions of political and public discourses.

Yet these numbers also show us that a considerable part of the population – 57 percent – positions itself *in between* the two poles. What is it that citizens in this politically more muted middle ground want? And are there points of consensus regarding migration beside and beyond the well-rehearsed disagreements of proponents and sceptics? What does society owe asylum seekers and refugees to fulfil the humanitarian duties enshrined

*Left: Newcomers to Germany in autumn 2019: temporary accommodation for refugee families in a hangar at the former Tempelhof Airport in Berlin.*

in the German constitution and the Geneva Convention? How much labour migration should be allowed? Who should be allowed to come to Germany, with which conditionalities, and what can legitimately be expected from newcomers and settled migrants? Citizens’ answers to these questions draw on a wide repertoire of normative standards, economic, cultural and political considerations. In the following, we summarise some of the most central positions and arguments found among the wider public, drawing on a recent study for which we gathered extensive survey and focus group data.

First off, it should be noted that German migration attitudes have remained remarkably stable in the last three decades. This is surprising when you consider that society has changed significantly as a result of the increasing share of migrants, and that we saw heated – and at times violent – episodes of political contention over the issue in the early 1990s and in the aftermath of 2015’s “summer of migration”. Although newer data hint at a souring of the mood in recent months, on average German citizens have become neither significantly more sceptical nor more open to migration since the early 1990s.

What has changed is the salience and importance of migration as a political issue. Citizens’ views of migration today are much more decisive for their electoral choices than they used to be. And especially on the right, positions have hardened and radicalised since the anti-immigration party *Alternative für Deutschland* (AfD) has entered the parliaments.

Overall, our representative survey of over 2,500 Germans shows a mixed picture, in which migration attitudes are characterised by an attitude of *conditional inclusivity*. There is a widespread realisation today that Germany has become a society marked by immigration, a self-understanding captured by the once contentious but now widely accepted term “*Einwanderungsland*”. Strict exclusionary measures in the service of ethnic homogeneity are seen by many as both impossible and normatively undesirable.

At the same time, the majority of citizens places conditions on migrants’ access to the territory and their membership in the national community. They distinguish between more or less deserving migrants, based on criteria such as the migrants’ humanitarian need of protection and aid, their cultural and social proximity and the degree to which arrivers conform to expectations of integration and hard work. The German “culture of welcome” is directed first and foremost at migrants whose perceived cultural foreignness remains limited (e.g. white Ukrainian Christians), those who are assumed to be in “genuine” need (such as mothers and children fleeing war) or those who are seen as compatible with the demands of the German labour market and its shortages of skilled labour.

Conversely, exclusionary impulses emerge with great predictability wherever Germans suspect an unwillingness of migrants to integrate or where immigrants are assumed to be motivated by “selfish” or “merely economic”, rather than humanitarian, reasons. These conditionalities and suspicions, which often draw on ethnic, cultural and gen-

### Thematic Series

The current Science Year is dedicated to the subject of “Freedom”, focussing on milestones in the history of democracy in the Federal Republic of Germany and the fundamental values associated with it: the 75th anniversary of the Basic Law in May and the 35th anniversary of the Peaceful Revolution in November. Through its series “Freedom, democracy and ...”, *forschung* seeks to contribute to public dialogue and media debate. The aim is to show in a selection of examples and from issue to issue how freedom-related topics are the subject of very varied research projects funded by the DFG. The spectrum ranges from the question about “freedom and migration” (in this issue), notions of “democracy and freedom of research” or “urban development and democracy” through to the research concept of “denied freedom” in this year’s final issue.

RU

dered stereotypes, mark the limits of conditional inclusivity. The simultaneity of inclusionary and exclusionary tendencies is what characterises the attitudes of most citizens. Only minorities (albeit often politically articulate ones) want to close – or open – the borders altogether. Both sides of the debate introduce conditions, differentiations and exceptions that modified straightforward pro- or anti-migration positions. The argument overall rages less between “Yes” and “No” than between “Yes, but ...” and “No, but ...”.

To understand this pattern better, we analysed material from focus group discussions: Here, we asked people from different socio-struc-

tural characteristics (such as income and education) and widely diverging opinions to engage in moderated discussions about controversial issues. Discussions around migration here stuck out as particularly polarised and well-rehearsed. Many participants not only had a clear sense of their own stance on the issues, but were also familiar with the arguments put forward by the other side and already anticipated their response.

In addition, it was notable that controversies often arose within a defined corridor of opinions defined by implicit points of *consensus* that were shared across the different positions. Virtually, all proponents of migration as well as sceptics and those with less decided views agreed that immigration should be subject to farsighted control and steering. Practically everyone regarded the reception of refugees from warzones and regions hit by famine and natural disasters as a relevant ethical duty and agreed that immigration could in principle be beneficial to the German economy under the right conditions. Virtually all of them subscribed to the goal of migrant integration through

labour market participation and the linguistic assimilation. These – often unspoken – points of consensus are interesting in their own right. But they also structured conflicts: heated and contentious disputes often concerned the question of how exactly consensual goals, such as migration control and migrant integration, were to be achieved.

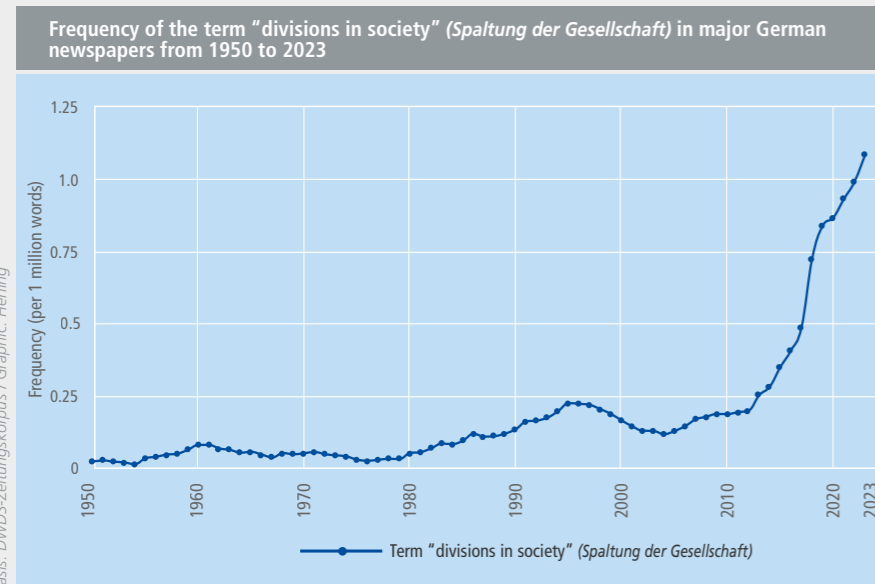
Our analysis distinguishes between two main areas of conflict in the arena of migration politics: one relating to the *external border* of the national territory, the other to the *internal border* of national membership and citizen status. External state borders are key for discussions about the controllability and legitimacy of immigration. Here, sceptical attitudes are mainly based on fears that result both from latent xenophobia and the sense that a greater permeability of the border will result in a sudden and quickly escalating influx of people, a loss of control and excessive demands on national infrastructures. This stands in contrast with the idea that immigration can be prudently controlled without

violent exclusion, or at least while keeping commitments to humanitarianism and decency, and that steady migration flows are a necessary and normal element of successful contemporary societies.

Disputes regarding the internal or membership border focus in particular on the economic and cultural effects that immigrants have on German society. The ideal of integration here acted as a moral hypergood that both sides subscribed to: yet while the pro-migration side emphasised examples of migrants' motivation to work and their willingness to integrate, the other side centred on experiences of foreignness and deviance, citing the Muslim headscarf of "criminal clans" as tropes of cultural distance and threat.

The main difference lays in whether the majority of migrants were categorised as willing to integrate, with a few bad apples as the exception, or whether, on the contrary, the few good examples were the exception to an overall pattern of anomie and deviance. These debates also concerned the question of who or what was responsible for *unsuccessful* integration: those who viewed the majority of migrants as motivated individuals tended to blame the host society's racism and/or the failure of the institutional architecture of inclusion and integration as hampering integration efforts. By contrast, those who were more distrustful of the migrants' motivations saw *them* as the main culprits who are not fulfilling their part of the contract even after the German host society had shown itself so generous to them.

*Migration had been a major divisive issue already before 2015. In German newspapers, talk of "divisions in society" has become much more frequent over time.*



Basis: DWDS-Zeitungskorpus / Graphic: Herling

and hostility towards migration. However, there is a significantly larger group in Germany that is not fundamentally opposed to migration and who wishes to continue fulfilling the country's legal obligation to protect asylum seekers and refugees. At the same time, this latter group expects policymakers to regulate immigration and facilitate successful integration. If this fails to happen in everyday life, while at the same time a dramatised image of migration is projected through public discourse, parts of the population are at risk of heeding the appeals of right-wing parties who have claimed ownership of the issue.

How far they will get with this is very much in the hands of those who bear political responsibility, as well as those who shape the way we talk publicly about refugees and immigration. Our analyses suggest that it is possible to counteract the radicalisation of migration-related conflicts. This would involve an empathetic focus on the human destinies behind migration numbers as well as clearly eschewing any racist differentiations between groups of migrants, even while organising the mechanisms of control necessary for a society of immigration.



Noisy protests and resentful messages ("Social stability in jeopardy: stop the multi-culti mania"): demonstration in Berlin in March 2023.

All in all, this leads to a mixed and partly contradictory image of migration conflicts in current German political opinion. Migration has become a crucial social issue and the obvious problems regarding finding lasting and effective solutions on the European level are contributing to the politicisation of the issue. When there is an increasingly widespread impres-

sion that neither the control of migration nor the integration of immigrants is successful, scepticism grows among the population. These impressions are stoked by right-wing populist and far right movements that capitalise on latent fears when they talk about "loss of control" or "foreign infiltration".

In our study, we certainly found entrenched attitudes of resentment



Illustration: Born / Stifterverband

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Illustration: Private

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Tomer J. Czaczkes

# Tiny Heads, Complex Thoughts

At first glance they seem interchangeable, yet on closer inspection they are individual: ants show definite parallels with humans – not least because of their excellent cognitive abilities. Researchers working in the areas of comparative psychology and behavioural biology examine them in the lab to gain a better understanding of how they think, feel, and experience the world.



*In action: A black garden ant (*Lasius niger*) moves on a "treadmill" during an experiment.*



Ants are everywhere – a closer look at a tree trunk or the grass in the park is enough to spot them. The little insects are famous for their efficient organisation and diligence. Researchers have been studying them for decades to understand how collective decision-making works. Yet most people do not see individual ants – or insects of any kind – as separate individuals. They are often thought of as interchangeable, characterless beings that function like tiny automata and perform simple tasks. For some time now it has become increasingly clear that this assumption does the insects an injustice.

But there is a problem in trying to demonstrate that this is not the case: individual ants are usually very difficult to distinguish from each other. In the lab, however, with a little acrylic paint and a toothpick, it is possible to quickly create lots of diverse individuals – each with a different spot of colour on its abdomen. This doesn't just look cute: after just a few minutes of observation it becomes clear that each ant is indeed an individual. When food is laid out in a maze, for example, one can quite quickly see that some of the ants are clever, while others are apparently rather stupid. Some are hard-working, some are lazy. Some are fast, some slow. However, in order to learn about their intelligence, the main challenge is to know how to ask them questions. Since ants are unable to talk (to us), we need to come up with the right tasks to challenge them with, in order to explore how their mind works. To take a straightforward example: if you let an ant drink just once from a sugar drop surrounded by lemon scent, it will then unerringly follow a lemon-scented path. This is a sim-

ple demonstration that ants are very fast learners.

In the lab, ants also turn out to be able to exercise excellent self-control – especially compared to children, as the well-known “marshmallow test” shows. This test involves children being seated in front of a marshmallow for a while: if they don't eat it, they get a second one later. Most children cannot resist the temptation. By con-

trast, ants are surprisingly successful here: if an ant tastes sweet food, it will normally eat it. But if it has tasted very sweet food beforehand, it will ignore the perfectly acceptable, mediocre food until it finds the “good stuff”. This behaviour shows a fundamental similarity between the economic thinking of ants and humans. After all, the value of things is often, for humans, relative: Whether

*Ants make collective decisions. This experiment shows that a colony manages to choose the better of two food sources entirely without a “boss” or hierarchy, and without any of the ants trying both food sources.*

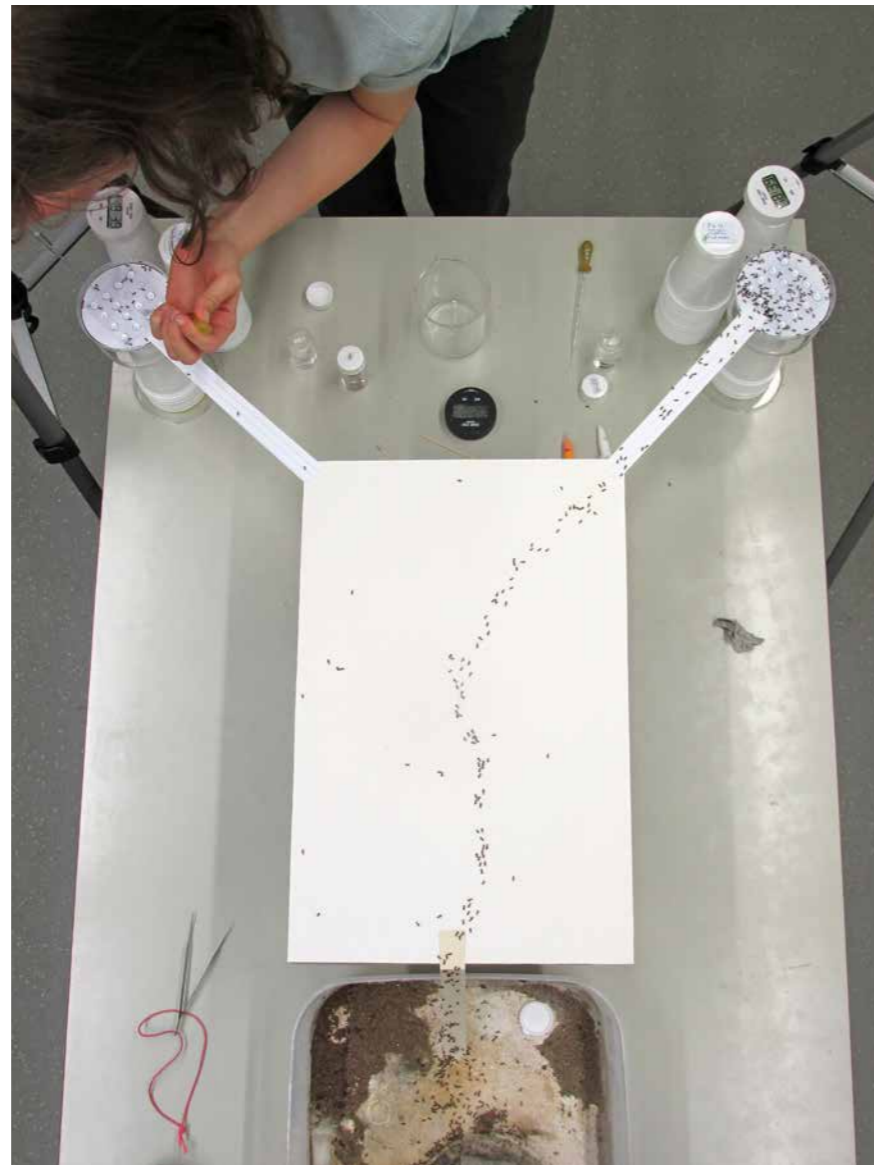


Illustration: Tomer Czaczkes



Illustration: Stephanie Wendt

*In “conversation”: When ants meet on their way, they exchange information and influence the expectations of their counterpart. Based on such encounters, they can even conclude whether the food source they are heading to is overcrowded.*

or not we consider our salary or workload to be acceptable depends mainly on how much our colleagues are paid and how much they work. Recent research has shown that this applies to ants, too. An ant expecting a bad reward is happy with a mediocre one, while an ant expecting a good reward is disappointed.

Ants show a wide range of surprisingly complex and cognitively demanding behaviours. One example involves a limitation some ant have: Most ants bring liquid food like honeydew back to the nest in their distensible abdomens. Ants that lack such a stretchy body solve this problem in a most unexpected way. They use tools – pieces of earth, twigs or leaves – as sponges to soak up the sweet liquid. They then carry these back to their hungry siblings. From the point of view of comparative psychology, not just their use of tools is impressive but also how adaptable their behaviour is: if they have a choice, they will use the most appropriate tool for the job. In the laboratory, they even prefer artificial

sponges to natural pieces of soil or leaf. They select the sponge of the appropriate size for the job and also make suitable tools if required.

The surprising thing is that these tools are not used by all the ants in a colony. If you take out all the tool users in an experiment, other ants start using tools instead – and you can predict which ones will do so depending on their personality. This shows that ants have personalities, and it is the brave, curious ones among them that are more likely to use tools.

Their excellent ability to learn, their cognitive complexity and the marked parallels they show with human psychology make ants an excellent model for understanding general psychological principles – overarching insights that are relevant to humans, ants, and many other organisms. Studying the psychology of ants can help us understand ourselves better. But why not just experiment on people? There are a number of reasons for this. Human test subjects have the advantage of being able to speak, but as test subjects they pose a number

of problems: they might question the procedure and will often try to outsmart the experiment or guess at what the researchers “want” to see.

Another, more subtle, problem is that it is impossible to separate a person from their social environment, education, and upbringing. For example, students give their own idiosyncratic answers to psychological questions and poorly represent humanity as a whole, yet the vast majority of studies in the field of comparative psychology and behavioural economics use the students themselves as subjects. What is more, cultural differences can modify or even reverse the results of psychological experiments, since culture masks or distorts the underlying mechanisms of human psychology.

Another factor is that there is (currently) a low level of ethical concern about using insects to carry out this type of study. Starving human subjects for several days to “increase motivation” would probably not get past an ethics committee, even less so the genetic manipulations that are used to study which neural pathways





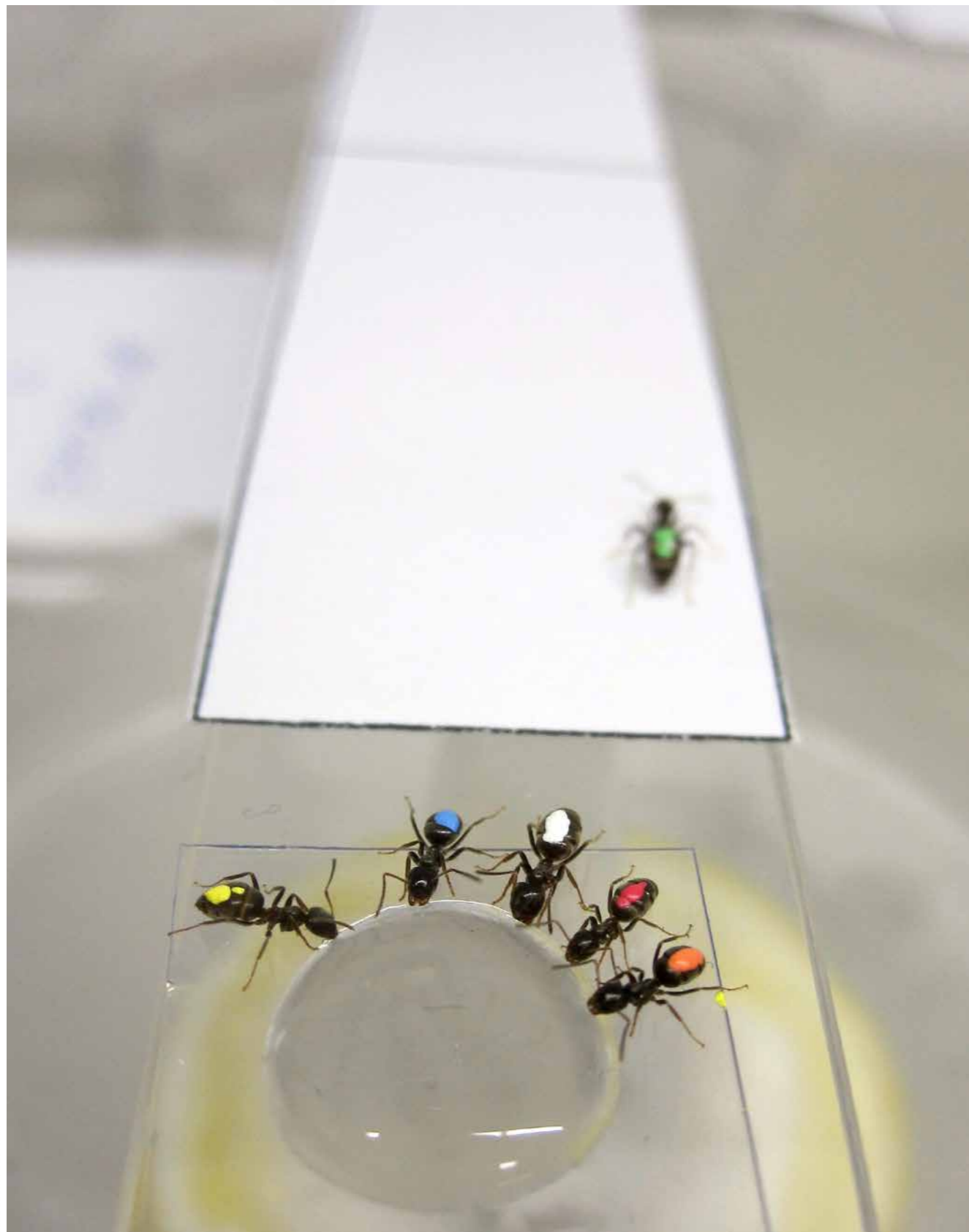


Illustration: Alex Koch



Illustration: Julia Giehr

*Left: Ants drinking from a sugar solution in the lab. Each of them is colour-coded. Above: No two are alike: After just a few minutes of observation, the different spots of colour on the ants' abdomens show how individual they are. Studying insects in the laboratory provides insights into general psychological principles that are relevant to many living things.*

are involved in behaviour. Nonetheless, we would do well to view this “advantage” with caution, given the growing evidence that insects feel pain and may be conscious beings.

However, research into ant psychology is still in its infancy. Up to now, researchers have mainly replicated human studies, initially defining parallels and differences between ants, humans and other animals. But this forces us to ask productive questions, such as: how is it possible to account for the differences observed? Often the answer lies in the fact that the biology is completely different, but sometimes there is another unexpected reason: human experiments are too easy! A lot of experiments in modern cognitive psychology consist of a test battery that involves performing hundreds of tasks on a computer. The extreme speed with which data can be collected in this way is very tempting. But are these tests really effective? Do these experiments truly mimic the psychology of the real world? By contrast, ants cannot be given instructions. They have to learn for themselves how

the world works through trial and error. The tasks that ants are given are real-life behaviours that reflect real needs. These essentially involve finding food and bringing it back to the nest. Thus, the findings yielded by such studies are highly likely to be relevant to the real world. For this reason, the first experiments have now been conducted in which people are tested like ants – i.e. running around in mazes, collecting rewards and learning the rules of the experiment through their own experience.

A growing number of studies demonstrate clearly that ants are cognitively complex and psychologically active creatures, and this likely holds true for many, if not

most, other insects. Comparative psychology is much more advanced in bees than in ants, for example, and also indicates marked parallels between humans and animals, even including surprising cognitive achievements such as simple arithmetic. Every ant, bee or beetle in our environment is a complex collection of memories and expectations, possibly with a conscious mind. Seen in this light, a summer meadow full of buzzing bees, fluttering butterflies and hopping grasshoppers becomes a metropolis full of striving and thinking individuals, making the world a place full of depth and wonder that is still largely not understood.



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**PD Dr. Tomer J. Czaczkes**

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[www.animal-economics.com](http://www.animal-economics.com)



Jörg Fehr, Joachim Linn, Marius Obentheuer and Michael Koch



Illustration: iStock / Gp photography

## Safe, Comfortable, Dynamic

“EMMA4Drive”: A new software prototype allows for the posture and behaviour of the driver to be simulated and evaluated more effectively in a wide range of different driving scenarios. It is based on a biodynamic human model that takes the place of static movement models. It offers another building block for the (partially) autonomous driving of the future.

Day-to-day life in Germany is car-based: more than 70 per cent of people in the Federal Republic currently use their car several times a week or even daily. The number of registered cars is continuously increasing – and there does not seem to be any sign of a trend reversal. For many people, autonomous or partially autonomous driving is a welcome vision of the future – the idea of being able to travel in your own car while at the same time making

sensible use of the time, for example, to check e-mails, relax, or enjoy a cup of coffee is appealing.

In addition, car sharing concepts using autonomous vehicles have the potential to make individual mobility more attractive for new groups or even make it possible in the first place. However, there remain questions, which are being discussed in the media and in society at large. Will it be possible to drive an autonomous car without a driving licence

in the future? How is it possible to improve safety in the vehicle and on the road? In view of this, there is also a demand for new vehicle interior design concepts: there are lots of possibilities here, ranging from small, one-person shuttles to large vans with collaborative workspaces. The expectations in terms of the possibilities of autonomous driving are high and wide-ranging.

Research is called upon to provide new digital tools to better address

*Left: Projection with autonomously driving vehicles at a motorway junction. Could this be a glimpse into the near future of private automobile traffic?*

these expectations. They should resolve the remaining questions with the aim of increasing confidence and demonstrating safety. Consequently, researchers in the “Data-integrated Simulation Sciences (SimTech)” Cluster of Excellence at the University of Stuttgart are collaborating with specialists at the “Mathematics for Vehicle Engineering” department at the Fraunhofer Institute for Industrial Mathematics ITWM, and together they have developed a muscle-activated human model. This model simulates the interaction between human body parts and the vehicle seat during driving manoeuvres. The resulting software prototype EMMA4Drive analyses and assesses safety and ergonomics as a digital twin of the occupants, while taking into account their active behaviour.

Experience confirms that during vehicle development, the changes

from one model or series to the next are usually comparatively small. For this reason, the assessment of ergonomics and vehicle safety has so far relied on knowledge that has been built up over decades. Here, various types of human models have become established as auxiliary tools for vehicle development during the digital phase.

In this project, the ITWM and SimTech teams are pursuing further development of their own dynamic human model EMMA and adapting it for use cases with fully or partially autonomous vehicles. This approach is also being combined with new possibilities available in the research literature, such as accident analysis. A distinction is drawn between the phases of an accident: in the collision phase, the so-called in-crash phase, highly detailed human and vehicle models are usually used to estimate the damage inflicted on human beings in such situations. Unlike crash tests with real vehicles and physical dummies, these simulations can be repeated and varied as often as

desired. They are also cost-effective because there is no need for expensive test technology, which often gets damaged during crash tests. At the same time, the simulations are very computationally intensive due to the enormous complexity of the models. They are only suitable for simulating a time range of a few milliseconds – not for reproducing active occupant behaviour over an extended period of time. Due to the long computing time, such an investigation therefore usually only considers a very small number of representatives and accident scenarios.

When assessing the ergonomics of vehicle occupants, (quasi-) static movement models (i.e. models that simulate only individual static postures or a temporal sequence of such postures) have become established in vehicle development. They are used during the design process, especially concerning the dimensions in the vehicle. Examples include the adjustment mechanism of the steering wheel or seat, while accounting

*Virtual test drives help the research team validate data and models. EMMA also learns to drive in the RODOS, the “RObot based Driving and Operations Simulator” (right, exterior view).*



Illustration: ITWM

for the height of the headliner or the arrangement of the pedals, to make them suitable for the greatest possible number of people. For this purpose, the various tools also provide functionalities to create manikins (i.e. individual representatives of the digital human model) with different body shapes. The aim here is to represent a wide range of diverse individuals.

Over the years, a workflow has been established for both long-computation approaches with soft tissue modelling and quasi-static movement models, which is tailored to recurring, similarly designed use cases. Yet for many challenges that arise in connection with the completely new concept of autonomous driving, these approaches are outdated since they are unable to draw on the knowledge provided by a previous model.

Autonomous driving raises entirely new questions with regard to comfort and safety. This applies not only to fanciful future visions of being driven to one's destination completely autonomously but also to the, for now, still necessary requests for the human driver to take over control of the vehicle from the mo-

torway pilot ("takeover request") in dangerous situations or before exits. This raises crucial questions for the safety of road users, for example: how long should the takeover time be until the person driving is fully in control of the vehicle again, depending on their position and activity?

Autonomous driving adds another dimension: the design of the assistance systems. Firstly, from the point of view of comfort: which driving style is perceived as pleasant for the activity in question? And in terms of safety: in scenarios where humans often no longer react at all or only do so reflexively, assistance systems with fast-calculating processors are often able to intelligently choose between different response options. Here it is important to consider the risk of harm to occupants, too.

In facing these new challenges, the software tools must simulate longer durations, involving the active behaviour of the people in the vehicle, where inertia effects play a key role due to the dynamic nature of the driving scenarios. For this reason, both long-computation models

and purely quasi-static movement models are unsuitable.

Therefore, "EMMA4Drive" adopts a new approach that seeks to advance the dynamic human model EMMA in order to investigate these types of scenarios. Due to the generic approach to movement generation and the realistic representation of humans and their muscular system as a biomechanical model, the tool is also able to provide realistic predictions for human movements during these new driving scenarios. EMMA does not require any hardware set-ups. The response of the digital twin changes when there are changes to the physical variables (such as weight and external forces, also resulting from accelerations). In earlier investigations, EMMA achieved realistic movement predictions, e.g. in assembly planning, compared to the recorded behaviour of people in experiments. The challenge in adapting EMMA for (autonomous) driving lies primarily in adequately representing the interaction between the person in the cabin and the vehicle interior – without losing the advantage of fast computing time.

*The IPS IMMA digital human model takes a short break in the vehicle. EMMA helps in assessing comfort during dynamic driving manoeuvres even in such "relaxed postures".*

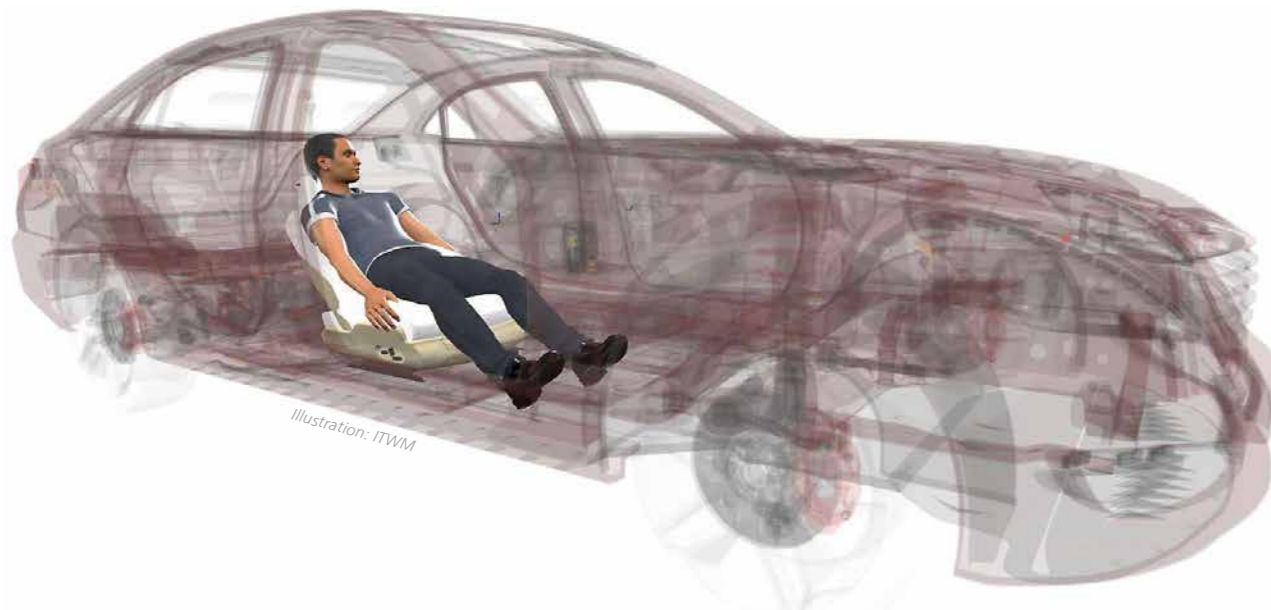


Illustration: ITWM

The human model uses an optimisation algorithm to automatically calculate new postures and entire movement sequences with the associated muscle activities over long durations. This approach enables the researchers to investigate the effect of dynamic driving manoeuvres on the occupants and their (response) behaviour. In this way, "EMMA4Drive" offers simple implementations of new movement patterns and efficient virtual investigation of safety, comfort, and ergonomics in autonomous and partially autonomous driving. The interaction between the occupants and the vehicle interior is represented by a surrogate model that is based on detailed offline simulation data and can be quickly evaluated. By drawing on this model, EMMA optimally incorporates the interior when calculating movements.

Before EMMA is allowed on the road, she must first pass her driving test – which is done virtually in the interactive driving simulator RODOS

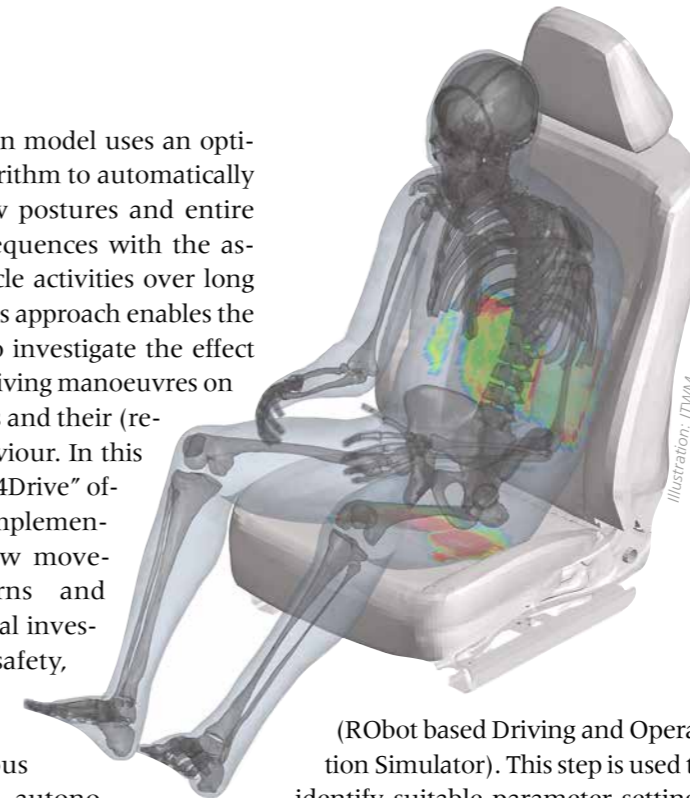


Illustration: ITWM

(RObot based Driving and Operation Simulator). This step is used to identify suitable parameter settings that allow for realistic movement predictions. For example, a person who is closely following the surrounding traffic will be better prepared for an emergency braking manoeuvre. This will in turn affect this person's behaviour and sense of comfort, especially when compared to a person who is engrossed in another activity and is taken by surprise.

Further investigations into this effect are required and utilize both the ITWM's driving simulator RO-

*EMMA's bone model is based on established occupant simulation models, enabling the obtained movement data to be further utilized in other models focussing on e.g., crash simulations.*

DOS and the driver's seat developed at SimTech. To assess the simulations performed by EMMA, the researchers conduct numerous driving tests and simulate different scenarios involving varying speeds and accelerations – including lane change or braking manoeuvres. In these tests, the participants seated in the vehicle are either instructed to follow the traffic closely, to keep themselves busy working on a tablet, or to relax with their eyes closed and the seat in a reclining position. During the experiment, the researchers track the participant's posture and movements and measure the resulting seat pressure distribution. In addition, the subjective perception of comfort is recorded through a questionnaire. In this way, the researchers derive correlations between body segment speeds, the seat pressure distribution, and the reports of comfort. This enables the evaluation of new scenarios for the autonomous driving systems of the future.



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**Dr.-Ing. Marius Obentheuer**, also from the Fraunhofer ITWM, is the head of the "EMMA4Drive" project.



**Dr.-Ing. Joachim Linn** heads the "Mathematics for the Digital Factory" department in the "Mathematics for Vehicle Engineering" unit at the Fraunhofer Institute for Industrial Mathematics ITWM.



**Dr. Michael Koch** functions as the coordinator at the ITWM spin-off fleXstructures GmbH, which provides application-oriented test scenarios for the "EMMA4Drive" project and he is also responsible for the dissemination of research results to the vehicle industry.

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[www.itwm.fraunhofer.de/en/departments/mf/digital-human-models-human-machine-interaction/emma4drive.html](http://www.itwm.fraunhofer.de/en/departments/mf/digital-human-models-human-machine-interaction/emma4drive.html)



# When There's a Bang in the Universe

Collisions of neutron stars reveal a lot about how matter behaves in extreme conditions. A combination of more observational data, finer analytical capabilities and innovative simulation models is now enabling new insights.

*Made visible with supercomputer animations:  
Before merging with a black hole, a neutron  
star is torn apart by tidal forces.*

A major breakthrough was made in the field of modern astrophysics on 17 August 2017: by means of a joint effort, researchers were for the first time able to measure gravitational waves and electromagnetic radiation from one and the same source. The observation involved a total of about 70 observatories on Earth and in space and about 3,000 researchers – a mammoth undertaking! The electromag-

netic radiation measured in addition to the gravitational waves covered the entire observable spectrum, from radio waves and optical light to X-rays and gamma rays.

Studying these observational data in detail showed that they were all related to a collision between two neutron stars. This collision took place a long time ago in the distant galaxy NGC 4994. Because of the large distance, it took

130 million years for all these signals to reach Earth.

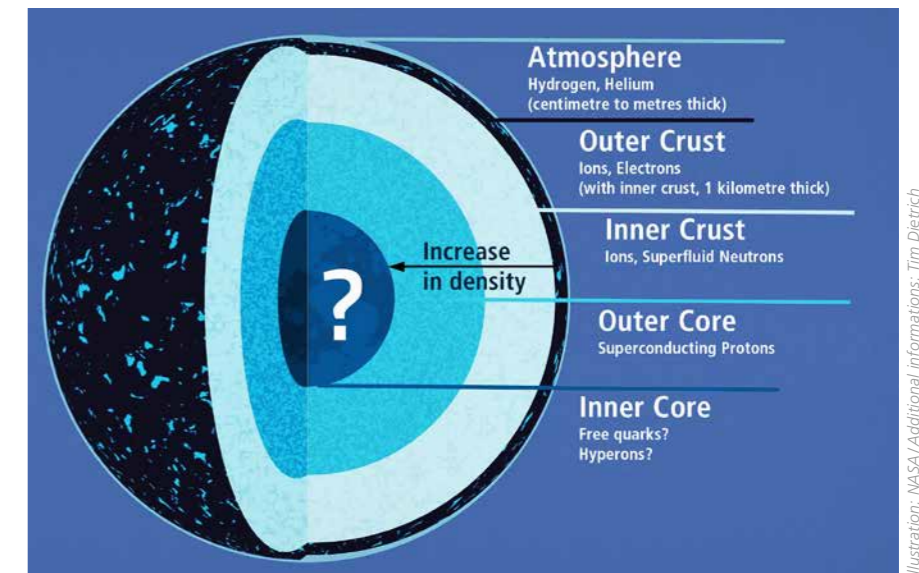
Neutron stars are fascinating astrophysical objects in themselves: they are the compact remnants of heavy stars. Although some neutron stars can be twice as massive as the sun, they have a radius of just ten to 15 kilometres. This makes them among the densest objects in our universe. A single teaspoonful of neutron star material would have a

mass of about one billion tonnes – equivalent to one hundred thousand times the mass of the Eiffel Tower.

Like other astrophysical objects, there are many neutron stars that exist in systems consisting of several celestial bodies. Some of the most interesting of these systems are binary neutron stars, i.e. systems consisting of two neutron stars. In such systems, the neutron stars orbit around each other continuously, their motion causing them to emit gravitational waves, i.e. tiny ripples of space-time. Although the gravitational waves arriving on Earth are very small – the measured spatial changes correspond to only a thousandth of the diameter of an atomic nucleus – it is possible to measure these space-time oscillations on Earth using state-of-the-art technology, namely an international network of gravitational wave detectors.

As energy is released from the binary system when the gravitational waves are emitted, the distance between the stars is slowly but continuously reduced until they collide. While being extremely fascinating, these collisions are difficult to calculate correctly. In order to do so, the equations of general relativity have to be solved. These equations and the system to be described are so complex that numerical solutions can only be arrived at using supercomputers.

Even if many thousands of computer cores are used simultaneously, such numerical relativity simulations take weeks or months. The sheer computational effort involved becomes even more apparent when one realises that current supercomputer simulations are only capable of simulating a few hundred milliseconds before and after the



Schematic structure of a neutron star. A combination of theoretical calculations and new observational data offer new insights into their composition.

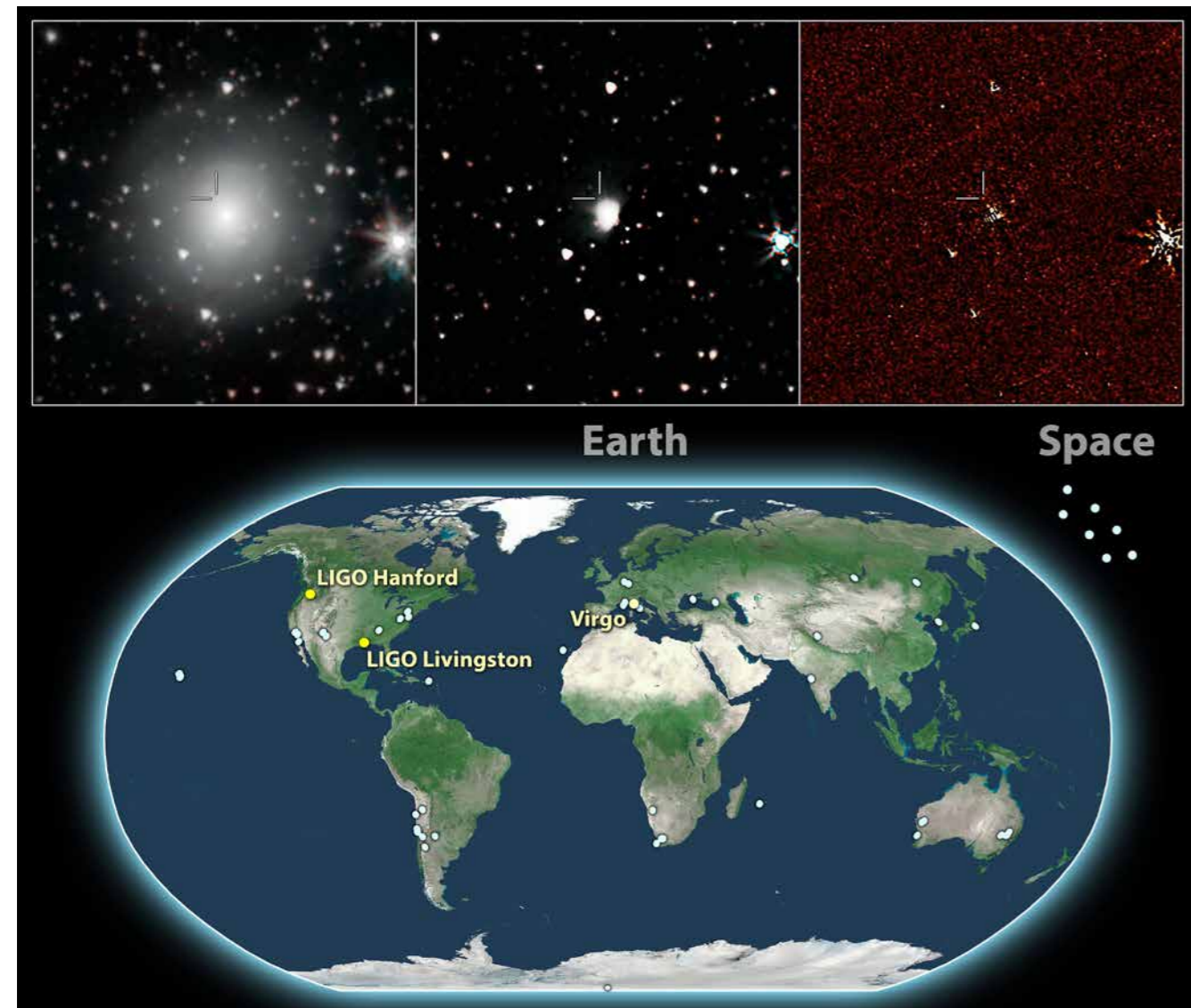
stars collide. In view of this enormous computational effort and the costs it involves, other ways must be found to evaluate the measurement data efficiently.

Simpler models are needed that allow gravitational wave signals to be calculated quickly and cheaply. State-of-the-art methods combine a large number of numerical simulations and new analytical calculations that do not describe the motion of neutron stars exactly but provide “approximate solutions”. Using this combination of numerical simulations and analytical calculations, new models can be developed that calculate a complete gravitational wave signal of colliding neutron stars within a few milliseconds. The use of such “waveform models” is crucial when it comes to interpreting the measured gravitational wave data and extract the information correctly, but such computer simulations not only provide information about the emitted gravitational wave signal. They also help find out whether and in what form matter

is ejected from the system. Within this ejected material, the heavy elements of the periodic table can form due to the high neutron density and the so-called rapid neutron capture. For this reason, collisions of neutron stars are an important production site of heavy elements in our universe: most of the gold and platinum we find on Earth was created when neutron stars collided.

Furthermore, radioactive decay of unstable, newly synthesized heavy elements heats up the ejected material, causing a kilonova, an electromagnetic counterpart observable a few hours to weeks after the collision. Indeed, kilonovae are bright electromagnetic signals that are characteristic for neutron star collisions. After observation, the data can again be analysed and compared with model calculations. In this way it is possible to gain a better understanding of the processes involved. If all the information from the gravitational wave and kilonova analyses are then combined, a precise insight into the collision process emerges.

A milestone in modern astrophysics: in August 2017, the gravitational wave detectors advanced LIGO (USA) and advanced Virgo (Italy) picked up the signal from two colliding neutron stars for the first time. This was followed by further measurements from about 70 observatories on Earth and in space (map). Above: Observations of the afterglow through the Spitzer Space Telescope in the infrared range, about six weeks later.



Aufnahmen: NASA/JPL-Caltech

Illustration: ESO/LIGO-Virgo

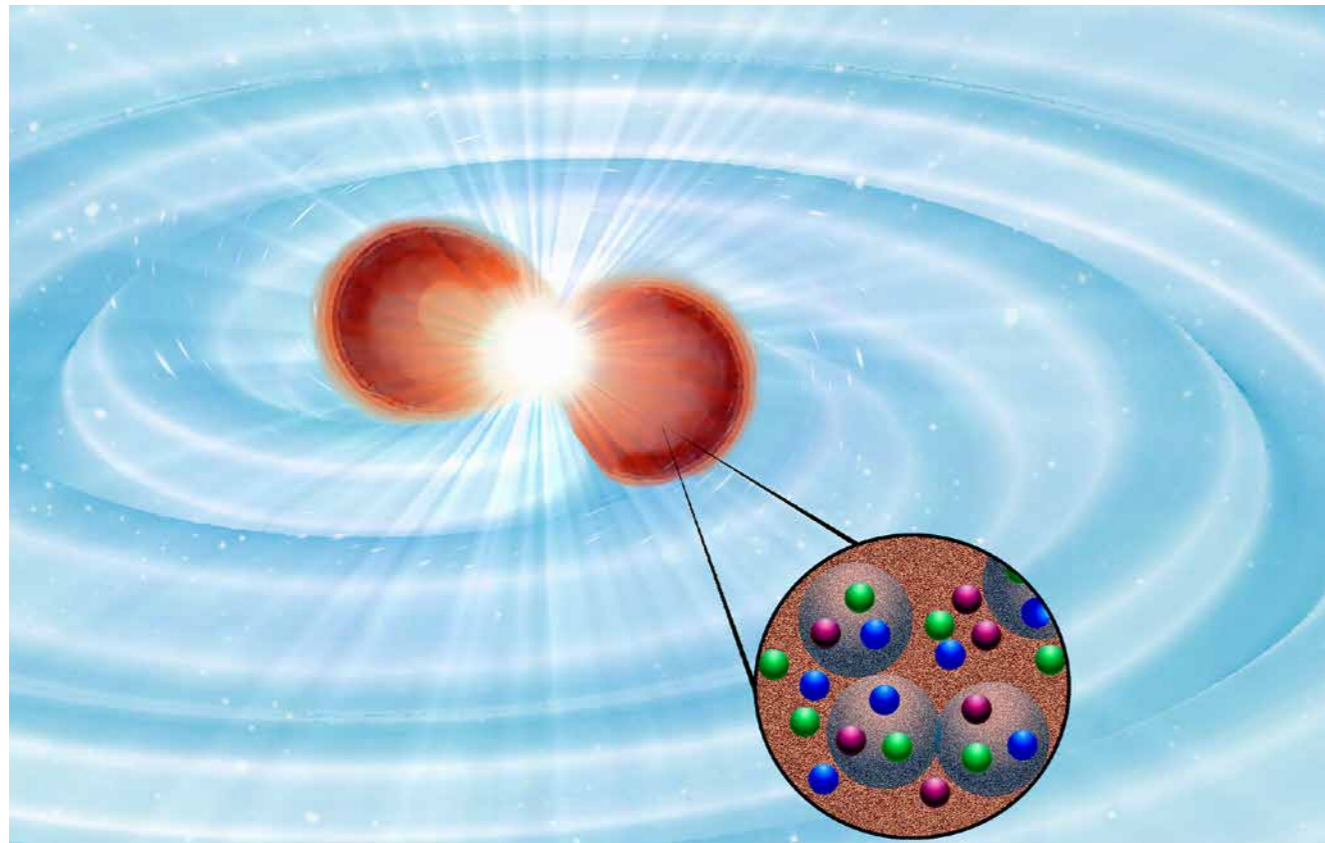


Illustration: Tim Dietrich

When two neutron stars merge, gravitational waves and electromagnetic waves are emitted. Interpretation of the signals allows the interior of the stars to be studied. In this way it is possible to understand the properties of matter under the most extreme conditions in the universe. The red, blue and green dots show quarks (elementary particles) with their different colour charges.

This is also an important aspect of studies carried out by our working group, namely that additional information can be incorporated during the analysis in order to obtain a comprehensive global picture. The method is similar to that used by a detective trying to understand as many details of a crime as possible. In our case, in addition to the analysis of gravitational waves and the kilonova, theoretical calculations from nuclear physics are used, as well as radio and X-ray measurements of individual neutron stars and neutron star collisions.

This information base – or more precisely the interlinking of different sources of information – allows us not just to investigate the formation

of heavy elements but also study the composition of neutron stars. This is of fundamental importance, since only neutron stars achieve densities that are many times greater than the density of an atomic nucleus. This is why the study of neutron stars enables the investigation of matter in its most extreme form – thereby enabling conclusions to be drawn about fundamental concepts of physics.

What is absolutely fascinating is that neutron star collisions not only permit significant advancement in studies on nuclear physics. The measured collisions also give us a better understanding of the properties of the universe on cosmological scales: using the analyses described

above, it is possible to determine the distance to the neutron star collision. In the case of the measurement of the neutron star merger on 17 August 2017, this was approximately 130 million light years.

Measuring the distance can help determine the evolution of the universe more precisely. After all, the universe is not static: it is constantly expanding. Two pieces of information are needed to measure the rate of this expansion: first, the distance to a defined source and second, the speed at which the source is moving away from us. The latter is obtained from neutron star collisions by observing the galaxies in which they are located.

Due to the movement away from the Earth, the light of the gal-

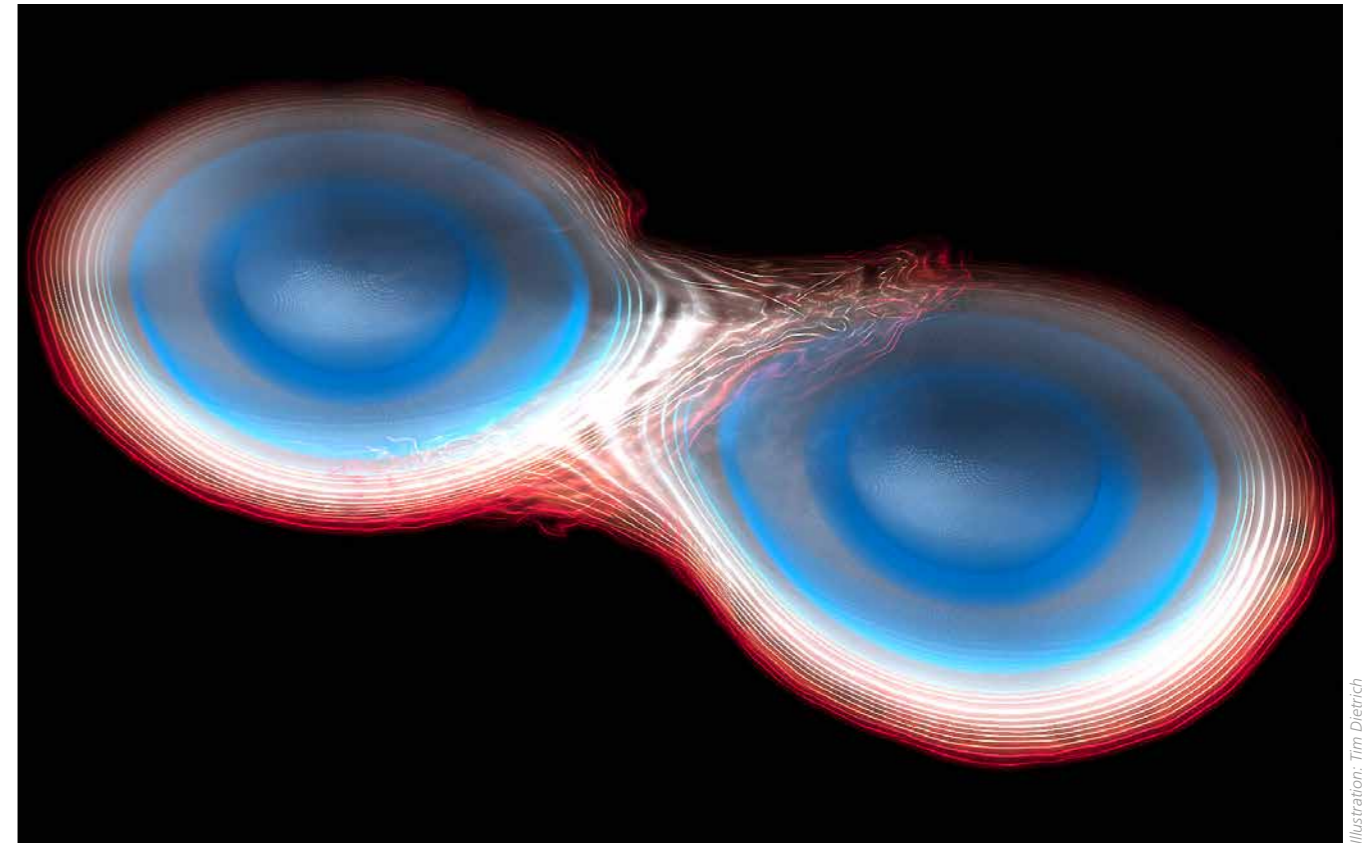


Illustration: Tim Dietrich

A distinctive spectacle: Two merging neutron stars in the simulation. Shortly before the collision the stars deform so that their outer layers are already touching. Increasing densities are illustrated here – from red to blue. The density within the stars is many times more than that of atomic nuclei.

axy changes slightly to a reddish colour. This means it has a slightly lower frequency. We are all familiar with this effect – also called the Doppler effect – from an ambulance moving away from us with its siren sounding. In this case, too, the frequency becomes lower and the sound deeper. If we now link the measured redshift of the galaxy to the distance from the neutron star collision, we can determine the speed at which our universe is expanding.

This shows that neutron star mergers are universal tools to study fundamental physics principles. They can help us gain a better understanding of the properties

of ultra-dense matter, track down the origin of heavy elements and measure the universe's expansion. The astrophysical community expects large numbers of neutron star collisions to be seen and studied in the course of the next few years using constantly improving telescopes

and research facilities. One thing is already certain: unravelling further cosmic secrets requires not only ever more precise measurement data but also highly complex computer simulations that make it possible to describe the physics involved in the collision of stars in detail.



Illustration: Thomas Roese

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is Professor of Theoretical Astrophysics at the University of Potsdam and Max Planck Fellow at the Max Planck Institute for Gravitational Physics in Potsdam. He was awarded the DFG's Heinz Maier-Leibnitz Prize in 2021 and received an ERC Starting Grant to study binary neutron stars in 2022.

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Lukas Schmidt-Mende

# Solar Cells Printed by the Metre?

Silicon as a semiconductor material is now facing competition. A good ten years ago, it was observed that chemical compounds with a special crystal structure – perovskites – could be used to produce solar cells. One particularly interesting feature is that they can be formed from solvents like a semiconductor ink. This gives rise to creative ideas for the future.

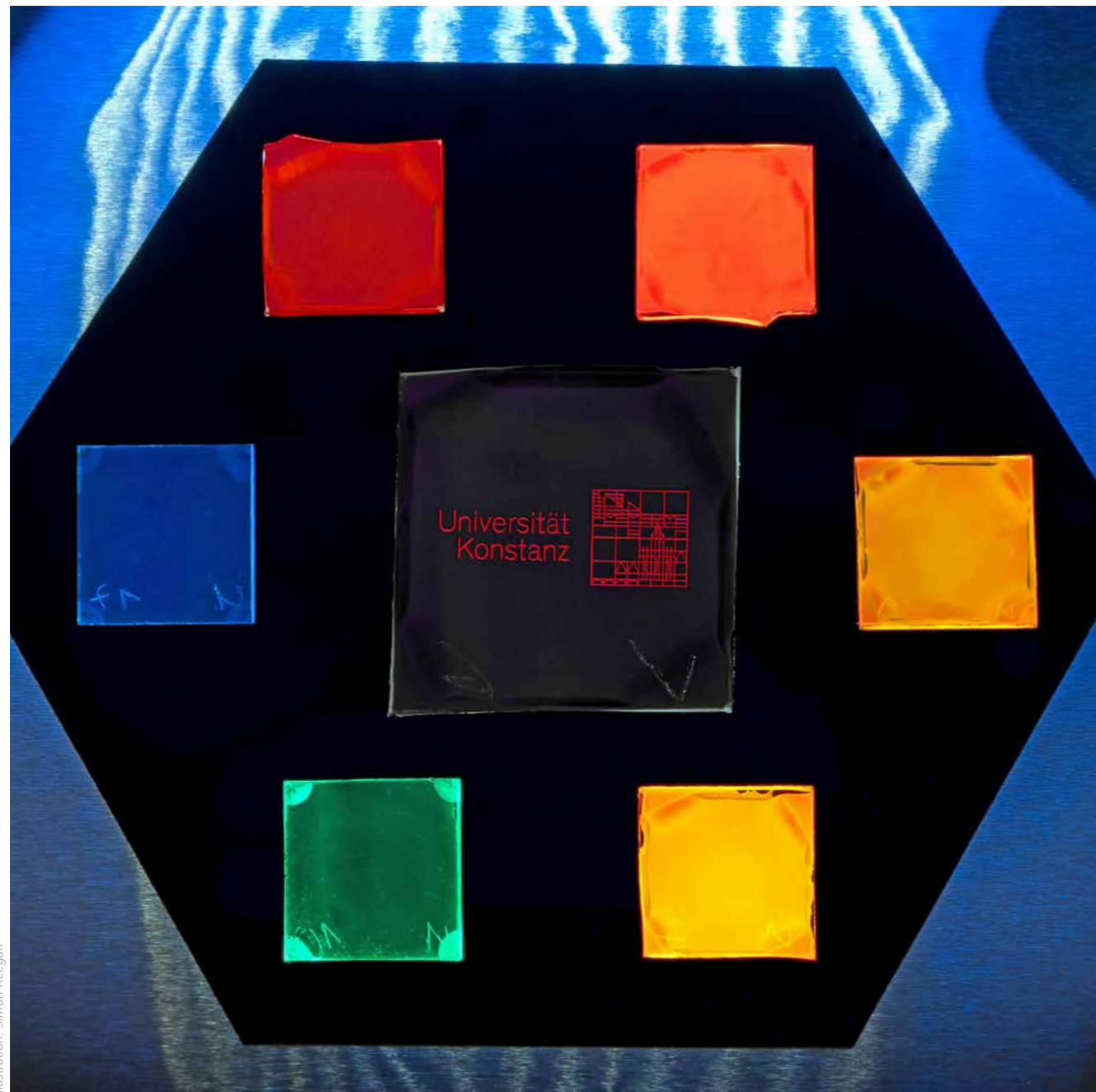


Illustration: Simon Keegan

Power-generating transistors, light-emitting diodes or solar cells – all these everyday technologies are based on semiconductors. They are solids whose electrical conductivity is very low compared to metals, but which under normal conditions have a significantly higher conductivity than insulators, also called non-conductors. This special property means they are of interest for a range of electronic and optoelectronic components, i.e. those that function in combination with light. An entire industry has developed from this – the semiconductor industry. The most commonly used semiconductor material for such components is silicon. But many researchers are looking for new semiconductor materials with even better properties for the desired applications.

Where does the special conductivity of semiconductors come from? It is their so-called band structure: this refers to the states of electrons which – when they lie close together – can be described as energy bands. One differentiates between a conduction band and a valence band, each at different energy levels and separated from each other by a band gap. Only the electrons in the conduction band can contribute to conductivity; however, the electrons must first be moved from the valence band to the conduction band, otherwise there are no free electrons available in the conduction band. Particles can be excited in this way by means of either temperature or light. Sufficient energy is required to overcome the band gap: visible light in the wavelength range of about 400 to 800

*Left: Perovskite films fluoresce when illuminated with UV light. A laser-structured sample shows where the author is researching.*



Illustration: Lukas Schmidt-Mende

*Measurement of solar cells: One of the aims here is to determine at which wavelengths the solar cell converts how much of the irradiated light power into electricity.*

nanometres can produce an excitation of the electrons in semiconductors, for example. But the matter is not entirely straightforward. Which wavelength really provides sufficient energy depends on the width of the band gap – which in turn depends on the semiconductor material. This means that the larger the band gap, the more energy is required and the more energetic and therefore shorter the excitation wavelength must be.

For some years now, materials have come into focus whose band gap can be varied by their chemical composition: perovskites – compounds with a specific crystal structure. These exist in a variety of different elemental combinations. Not all of them have semiconducting properties, but about ten years ago research teams discovered that some of these perovskites are suitable for building solar cells. Depending on the choice of chemical composition, the perovskites' band gap changes – in contrast, silicon has a

fixed material-dependent band gap of 1.1 electron volts. Since the band gap of a semiconductor determines its optoelectronic properties, perovskites offer a great advantage in the construction of tandem solar cells, for example.

The discovery that metal-halide perovskites are excellent semiconductor materials for solar cells gave an enormous boost to this field of research. Perovskite solar cells are now known in which a quarter of the power from irradiation by light is converted into usable electrical energy. This makes them similarly efficient to conventional silicon solar cells. In addition, perovskite semiconductors have already been used very successfully for light-emitting diodes. It seems promising to use the material for lasers or in detectors for different wavelength ranges, too.

When used for the manufacturing of components, perovskites also demonstrate distinctive features compared to other materials. In the melt at high temperatures and with

a great expenditure of energy, silicon as a raw material is converted into high-purity silicon crystals. By contrast, perovskites can either be vapour-deposited at comparatively low temperatures or even dissolved in solvents and used like a semiconductor ink. For a long time, it was considered unthinkable that semiconductors made from a solution of this kind could match the performance of conventional semiconductors in devices. In solution processing, it is not possible to reduce the defects in the semiconductor crystal as much as would be necessary for conventional semiconductor materials such as silicon. But halogen-containing perovskites used have proved to be extremely defect-tolerant in terms of their crystal structure and, despite a comparatively high defect density, perform similarly well in optoelec-

tronic devices as conventional high-purity semiconductors.

The manufacturing process using solvents has one particular advantage: it can be applied to any substrate, for example by printing. In the future, this could mean that you could print your own solar cells or light-emitting diodes using an inkjet printer. By means of special printing processes, solar cells could be produced by the metre on films – and at tremendous speed. Even though such processes are currently still visions of the future, there is a real chance of them being put into practice at some stage. The new perovskite semiconductors offer this possibility. At the same time, their production requires only a fraction of the energy that conventional semiconductor materials would need to ensure the required quality.

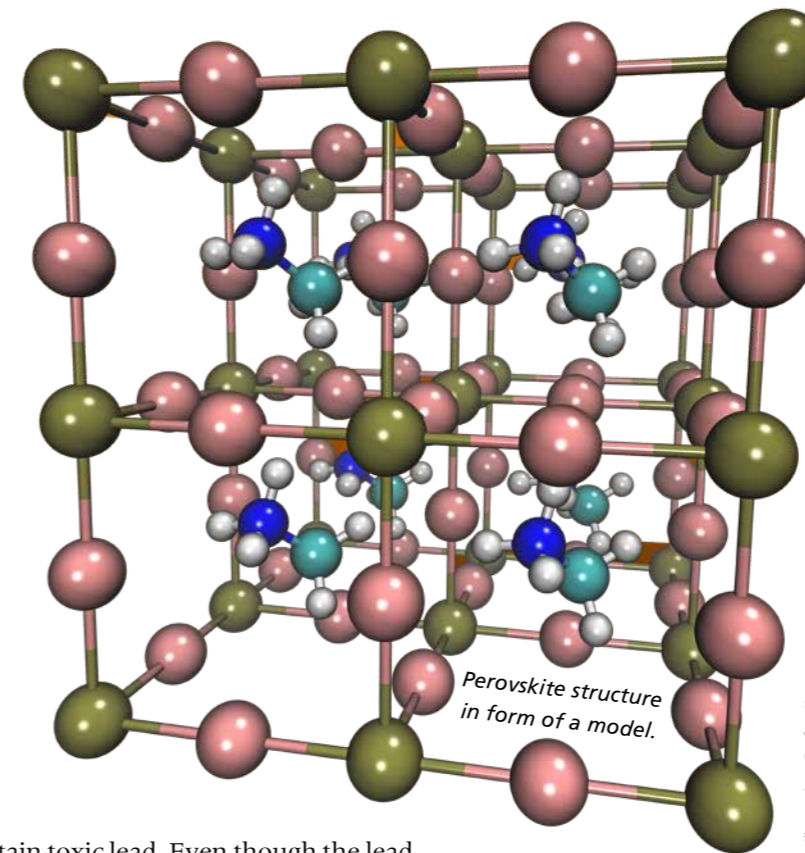
Besides the immense advantages and the great potential of this material, there are currently two key drawbacks. Firstly, perovskites are significantly more unstable than conventional semiconductors. This means that components based on them do not yet have the necessary service life in the same way as silicon components, for example. The material degrades more easily, and has to be extremely well encapsulated to keep moisture and oxygen out. While it can easily be produced in crystalline films without high energy input, it often seems to degrade again just as easily. Preventing this is a very important aspect of research right now, and it has already been possible to achieve impressive improvements in material stability.

The second disadvantage is that the highly efficient perovskites con-

*Manufacturing system for perovskite solar cells. In order to produce high-quality perovskite films, they are usually processed in "glove boxes" filled with nitrogen and containing hardly any traces of water or oxygen.*



Illustration: Lukas Schmidt-Mende



Perovskite structure in form of a model.

Illustration: Stefan Krämer

tain toxic lead. Even though the lead content in a device as a whole is very low, this is a problem that cannot be neglected. Researchers are working hard to replace the lead with other materials that are preferably less toxic or not toxic at all. Some attempts have already been very successful, but components made of lead-free perovskites have not yet reached the same levels of efficiency and are usually much less stable. Despite some remarkable results, research is still in its infancy here.

In addition to these two research aspects of stability and toxicity, there are many other fascinating unresolved questions to be pursued in the areas of chemistry, physics, and materials science. For example, it is still unclear exactly which defects form in detail and how these impact on the efficiency and stability of a component. Other questions include the following: what are the dynamics of defects, how and under what conditions do they form? What is their impact at interfaces? And how can their number be further reduced?

One loss mechanism in many electronic components is that positive and negative charge carriers neutralise each other by recombining. This effect is often caused by defects in the semiconductor material or at its boundary layers. While the perovskite semiconductor is the most important layer in devices, it is surrounded by other layers which help ensure that the charges in the component move as desired. The interfaces between the perovskite and the other layers play an important role, so forming an optimum interface is another important focus of research.

In terms of the various electronic and optoelectronic applications, a number of different strategies and developments are being pursued to increase efficiency. For example, research teams are working on the aforementioned tandem solar cells. Various approaches are being followed here, such as combining silicon solar cells with perovskite solar cells, but it is also possible to produce tandem solar cells consisting of

two different perovskite solar cells with individually tuned band gaps.

There are many other fascinating scientific aspects of this subject that researchers are currently investigating all over the world. Although research into metal-halide perovskite semiconductors is still at a fairly early stage – it has been just over ten years since the first breakthrough in 2012 – we are already seeing lots of highly promising possibilities and the first commercial applications are to be expected soon, such as Si-perovskite tandem solar cells.

Just how high the level of interest is in this research field worldwide is demonstrated by the numerous new findings that are published every day. Under the Priority Programme "Perovskite semiconductors: From fundamental properties to devices", a strong network has formed in Germany that is dedicated to pursuing many of the research questions mentioned. One thing seems certain: we can continue to expect exciting developments in this very dynamic area of research.



The physicist

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<https://perovskite-research.de>





Martin Loiperdinger and Yvonne Zimmermann

# A Star is Born from Marketing

Asta Nielsen and the introduction of the film star system before the First World War marked a significant turning point. The promotion of films starring the Danish actress pioneered an entirely novel approach at the time. Today, thanks to digitisation, scattered advertisements from both local and trade press can be consolidated, offering unforeseen revelations into the nascent film industry of that era.

*Colourised image enlargement from "The Film Prima Donna" (1913). Asta Nielsen plays herself, as it were, examining developed film strips in the darkroom.*

It was a momentous contract: in late May 1911, at the headquarters of the cinema chain Projektions-Aktiengesellschaft Union (PAGU), located at Kaiserstraße 64 in Frankfurt am Main, the Danish actress Asta Nielsen (1882–1972) signed an exclusive three-year deal for 30 feature-length films. The concept was revolutionary: cinema managers would commit to booking an Asta Nielsen series for each season in advance, oblivious to the specifics of the films, save for the assurance that they would all feature Nielsen's stellar performance. Thus, in Frankfurt am Main, the foundation of the star system in feature films was laid, a practice that would significantly influence Hollywood's marketing strategies well into the 1950s. Film companies would secure exclusive contracts with stars and capitalise on their audience appeal throughout the duration of the agreement.

At the onset of the 1910s, audiences worldwide were accustomed to varied programmes of short films and not accustomed to following a single film plot for more than fifteen minutes. Only a handful of multi-reel films, lasting no longer than three-quarters of an hour, had recently entered the market, with the leading actors' names typically not promoted.

When Nielsen signed her contract in May 1911, she was already familiar to German audiences through three successful feature films. However, the notion of placing a "blind booking" for several feature-length films was entirely novel to cinema managers. It was undoubtedly an enticing prospect for them to exclusively lease a series featuring Nielsen, leveraging their local screening monopoly. However, the production costs for the initial ten Asta



Nielsen films, each distributed in approximately 70 copies worldwide, amounted to a staggering 700,000 marks – an astronomical sum for that era. The primary investors, Cologne film dealer Christoph Mülleneisen and his Frankfurt partner Paul Davidson, were undertaking a substantial risk. In a full-page advertisement boldly titled "A first in the cinema industry", they proclaimed, "That takes courage!" (Der Kinematograph, No. 238, 19.07.1911; see page 35).

The research project "Asta Nielsen – The International Film Star and the Introduction of the Star System 1911–1914", conducted at the Universities of Trier and Marburg, delved into whether and to what extent the high-risk business model devised for the three Asta Nielsen series was executed in practice. With no surviving business correspondence or contracts, the local daily press served as a "scattered archive" of cinema history, reconstructing the distribution of Nielsen's films before the First World War based on cinema advertisements.

The well-structured and searchable platforms of digitised daily newspapers in respective national libraries were consulted to conduct studies in Austria-Hungary, Great Britain, Australia and New Zealand. However, for approximately 50 cities in the German Reich, microfilms had to be painstakingly searched due to the unavailability of digital copies of daily newspapers. For the 27 films starring Asta Nielsen released before the First World War, numerous advertisements and articles from film

*The "queen of mimic art" and the "film prima donna" – star marketing for Asta Nielsen in advertisement format. Advertisement in Freiburger Zeitung 1915 (top) and Kattowitzer Zeitung 1914 (bottom).*

industry magazines and local newspapers were collated in the freely accessible online project database "Importing Asta Nielsen Database" (IANDb), comprising over 15,000 entries from the five selected countries and nearly 2,000 from over 20 other countries. In addition to advertisements, the database contains early film reviews, interviews and literary portraits of the Danish actress.

The analysis of advertisements in the local and trade press unmistakably indicates that Asta Nielsen was indeed the pioneer star of feature-length films in the studied film markets. In Germany and Austria-Hungary, film distributors achieved significant success in meeting targeted sales of the Asta Nielsen series, despite the requirement for blind block booking. Conversely, in Great Britain, many cinema managers relied on verbal announcements in theatres, placing advertisements in the local press sporadically or irregularly. Nevertheless, trend analyses of 20 film stars in cinema advertisements in local press outside London confirm Nielsen's status as the benchmark star of feature films in Great Britain, evidenced by numerous "Asta Nielsen Weeks", featuring different films daily. Nielsen enjoyed exceptional popularity in Australia and New Zealand, where cinema audiences showed a vibrant interest in European cultural events and fashion. The sheer volume of digitally accessible local newspapers and cinema programme advertisements "down under" even facilitated tracing the distribution routes of individual film copies.

Brand advertising for Asta Nielsen films was particularly prominent in German cinema advertisements, with numerous cinema managers

Der Kinematograph — Düsseldorf. No. 238.

## Ein Unikum in der Kino-Branche!

Die „Internationale Films-Vertriebs-Gesellschaft“ hat bis zum 3. Februar 1912 für Mk. 1.400.000 Monopolfilms abzunehmen.

**Das heisst Courage haben!**

Die „Internationale Films-Vertriebs-Gesellschaft“ hat **keine Furcht**, dieses Quantum zu placieren.

**???? Weshalb????**

Sie besitzt den Star **Asta Nielsen** :: die Duse :: der Kinokunst  
 Sie besitzt den Schriftsteller und Regisseur **Urban Gad** der Autor von „Abgründe I.“

Mit diesen beiden Kapazitäten fordern wir **die Konkurrenz in die Schranken!!!**

Diese beiden Namen sind den Kinobesuchern in **Fleisch und Blut** übergegangen und garantieren **volle Häuser!!**

Die beiden ersten Ausgabetege sind für **Der schwarze Traum** | **Asta Nielsen, Urban Gad**  
**19. August** | **9. September**  
**Unsere General-Repräsentanten sind unterwegs!**

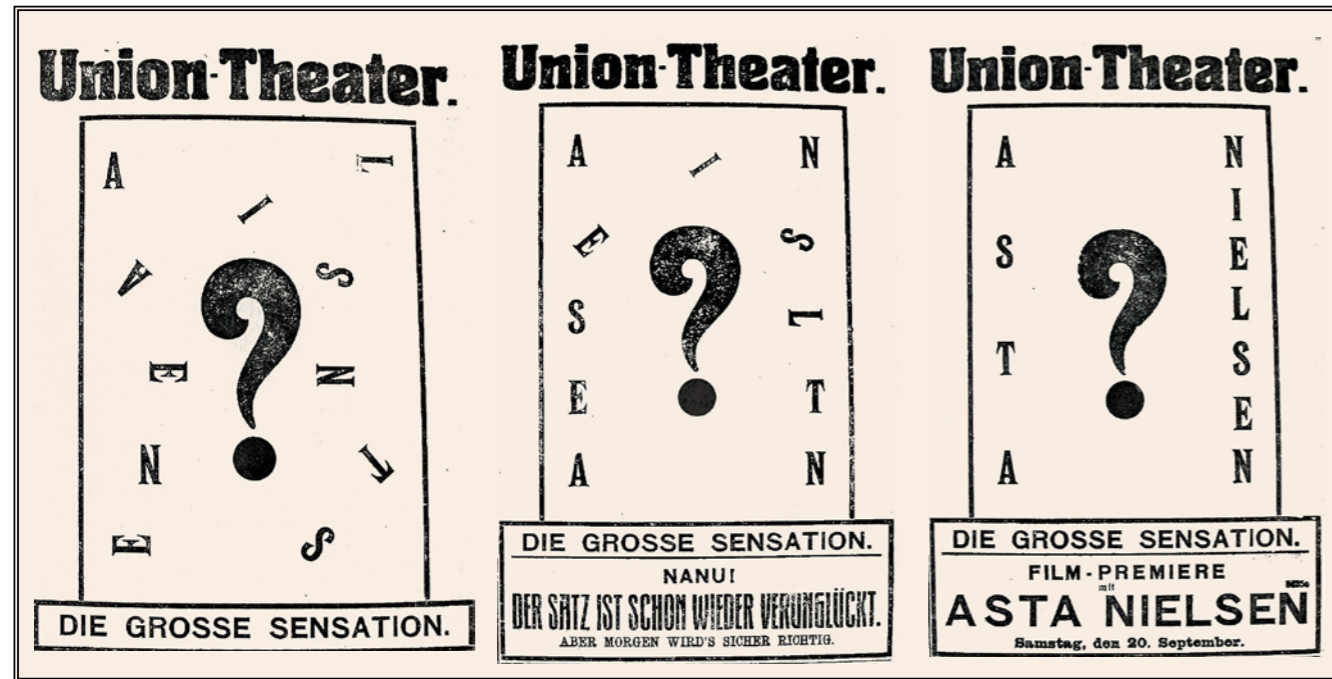
Anfragen sind zu richten an:  
**Projektions-Aktien-Gesellschaft „Union“**  
**Frankfurt a. M.**  
 Kaiserstrasse 64 | Telegr.-Adr.: „Aktges“ | Telephone: I, 12494.

*A distribution advertisement in the magazine "Der Kinematograph" in 1911 – the Asta Nielsen feature films were marketed aggressively.*

utilising distributor-provided templates featuring portrait and role vignettes of the film star, often based on star postcards. Nielsen's visual representation evolved from 1911 to 1913, transitioning from a young woman of humble origins to an elegantly attired lady and eventually to the "new woman", sporting a contemporary pageboy hairstyle. This

publicity primarily targeted urban theatre audiences – a burgeoning market for the film industry. Nielsen was frequently dubbed "the Duse of cinema art", a grand comparison elevating her to the stature of celebrated Italian theatre diva Eleonora Duse.

The concept of bundling feature-length films into series and marketing them through blind block book-



Illustrations: IANDB

These newspaper advertisements in the form of a brainteaser appeared in the Saarbrücker Zeitung for three days in succession in 1913 to promote the silent film "The Suffragette" starring Asta Nielsen.

ing alongside a star is often credited to Paramount producer Adolph Zukor. From 1915 onwards, Zukor would bundle a Mary Pickford film with several B-pictures, obliging cinema managers to book less profitable films alongside sought-after stars. This practice gradually tarnished the reputation of blind block booking. Conversely, the "monopoly star series" featuring Asta Nielsen guaranteed cinema managers that every film in the package carried the cachet of a successful brand: if it bore Nielsen's name, Nielsen was in it!

The Frankfurt business model, which exclusively distributed Asta Nielsen film series, proved successful, leading to an expansion of "monopoly star series" offerings in Germany, Austria-Hungary, Great Britain and other European countries from the 1913/14 cinema season onwards. Films starring Nielsen's German rival Henny Porten (1890–1960) were among those distributed in "monopoly film series". After withdrawing from the Frankfurt consortium, Cologne film dealer Christoph Mülleneisen introduced a Lissi Nebuschka

series, along with an exclusive series starring Suzanne Grandais, the leading actress contracted to the French company Gaumont, on the British film market.

Nielsen's reign in Europe came to a halt with the outbreak of the First World War, as Italian divas such as Francesca Bertini and Lyda Borelli rose to prominence, inheriting Nielsen's legacy. Despite the announcement of a fourth Asta Nielsen series for the vast market of the Russian Tsarist Empire in June and July 1914, it was never released. Although the films for this series were produced before the war, they were not premiered in Germany until the 1915/16 season.

Studies on brand advertising for Asta Nielsen underscore the pioneering role of major European film markets in establishing the film star system and feature-length films in the early 1910s, particularly through the successful Frankfurt business model employed for the Asta Nielsen series. Numerous imitations swiftly rendered the "monopoly star series" a standard feature of cinema enter-

tainment across Europe. Future research endeavours will seek to trace the structures and developments underlying this significant transformation in various countries and how the model of full-length "diva films" eventually found success within Hollywood's studio system.



Illustration: Marian Stefanowski

Illustration: U Marburg

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More than 18,000 advertisements and articles on the films featuring Asta Nielsen before the First World War are accessible online in the "Importing Asta Nielsen Database" (IANDb): <https://importing-asta-nielsen.online.uni-marburg.de>



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The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), a registered association, is the largest research funding organisation and the central self-governing organisation for research in Germany. Its mission, as defined in its statutes, is to promote research in all its forms and disciplines.

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For more information, visit [www.dfg.de/en](http://www.dfg.de/en)

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# #ZUSAMMENLAND

**VIelfalt macht uns stark!**

Dumpfer Populismus? Nein danke! Die sogenannte »Remigration« unserer Freundinnen, Nachbarn, Kolleginnen? Ganz sicher nicht. Und Faschismus? Nie wieder! Deutschland braucht keine Alternative zur Freiheit und Vielfalt. Wir haben aus der Geschichte gelernt und vergessen nicht, wie das Unmenschliche – zunächst heimlich und verhalten, dann unterdrückend und brutal – in die Gesellschaft eingedrungen ist. Die gegenwärtige Zeit erfordert eine klare Haltung. Wir stehen gemeinsam für ein offenes Land, das sich mutig den Herausforderungen stellt, anstatt sich von rechter Propaganda aufheizen und aufhetzen zu lassen. Denn wir wissen bereits, wohin das führen kann. Also, dieses Jahr zählt: Gegen Hass und Spaltung. Für ein neues Miteinander. Gemeinsam stark in einem vielfältigen **#Zusammenland**.



Eine Initiative von: **DIE ZEIT**, **Wirtschafts Woche**, **Handelsblatt**, **TAGESPiegel**, **Süddeutsche Zeitung**, **STRÖER**

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For cosmopolitanism and tolerance: like the DFG, several hundred organisations from science and the humanities, culture and education are participating in the spring of 2024 in the initiative #Zusammenland (English: Togetherland), a print and media campaign of major media companies in the Federal Republic of Germany.