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INTERVIEW

The truth in science

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Abstract Are natural scientists gaining an ever more complete picture of reality through their objective insights, or are the truths of the natural sciences no more than consensuses that change with time? The astrophysicist **Jürgen Ehlers** and the social scientist **Rudolf Stichweh** talk to Spektrum.

Spektrum: *Professor Ehlers, how valid is Newton's law of gravitation?*

Professor Jürgen Ehlers: Newton's law is a statement that should be considered correct, on certain scales and with a certain precision, not only for our own solar system but also for other double and multiple systems of bodies. The law was refined, corrected and extended by the theory of General Relativity, but that absolutely does not change the fact that this is an insight that will last for once and for all. It is valid independently of the culture in which it came into being, and independently by which particular people it was invented.

Spektrum: *Professor Stichweh, "once and for all": How would you react to that?*

Professor Rudolf Stichweh: The question is, what are we talking about? Are we talking about the text of the "Principia Mathematica", and what we read there—something which practically no one has done; the book was already "unreadable" when it was published, its archaic mathematical notation being incomprehensible to most contemporary readers. What do we mean when we say that it is valid for all time? Are we talking about the text of a book as it appeared in 1687, or are we talking about what a physicist says today, who is being selective and has decided that certain things are still valid.

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That is the difference between practising natural scientists and historians. Natural scientists make rational reinterpretations of these things and call them timeless realities. The historian of science reads the contemporary text and finds, in the original source, not an orderly progression of increasing insight, a certainty of progress, but rather incomprehensible ideas, idiosyncratic illustrations and absurd theories.

Ehlers: We are talking about the observation of facts: Newton tried to explain observations of the motions of points in the heavens with a theoretical picture. I can read the book in which Newton formulated his laws of celestial mechanics well enough to be able to say that I see no fundamental difference between it and the way in which we teach that part of physics today. The fact that Newton used Euclid's geometry and Appololonius' conic sections in his argument is only a superficial detail.

Of course, it is easier for us today to use differential calculus, but that is really only a translation—just as it is more difficult for me to read a French text on quantum mechanics than a German one. It is remarkable to what extent the factual content, as well as the experimental results from which Newton obtained it, remain valid. To me, this reference to reality is at least as important as referring to the text.

Stichweh: Actually we never talk about reality, but about particular theorems that scientists formulate regarding reality. Reality is always excluded.

We see reasoning and communication between scientists, where some approaches manage to convince and some do not. In fact, we are talking about discourse which seeks to influence further discourse. This indirectness has grown through the history of science: the externalisation of reality increases.

Spektrum: *Is reality disappearing from science?*

Ehlers: What I think is missing from Professor Stichweh's description is a consideration of experiments and observations. A given theory is only accepted in a scientific field when experiments agree with its theoretical predictions within certain sensible error margins (Figs. 1, 2 and 3).

It is at least as important to consider these things, which are not manmade, but which come from the outside, as it is to consider the theoretical discussions that are internal to ourselves.

Stichweh: I would make absolutely no distinction between that discourse which relates to theories and that which refers to experiment. I might draw a particular conclusion from my experiment, but that conclusion is not something which could be directly drawn from reality, and it could be disputed. We only talk to other scientists, whom we need to convince of our own interpretation of the experiment. Reality never enters into these discussions, but always remains "out there". There might always be someone who says, "That's a one-off effect," "That seems to me to be an unreliable technique", and so on. Reality never steps in to decide the thing for us.

Ehlers: I agree completely with that description in so far as it relates to the immediate actions of people. But let's take the the solar system as an example: From Eudoxus through Aristotle, Ptolemy, Kepler, Copernicus, Newton and down to Einstein. I believe that it would be reasonable to say of all that human endeavour, including both

Fig. 1 Jürgen Ehlers during the interview in 2001

Fig. 2 Jürgen Ehlers and the sociolocist Rudolf Stichweh

observation and theoretical development, that it has given us an ever more precise understanding of a given physical system.

Why can't one say that? That is the point that annoys me. If we disallow the concept of reality then a historian researching documents regarding the murder of Julius Caesar cannot say, "I have discovered something about a historical event, which definitely happened.", but instead he is only constructing a picture in his own head.

But any reasonable person would think, "My ancestors already existed many generations ago." Why is it that we allow ourselves to discuss reality, but then suddenly no longer allow it in the context of the natural sciences, where things are also constructed on the basis of directly available documents, namely experiments.

Fig. 3 From left to right: Reinhard Breuer (Editor-in-Chef of Spektrum der Wissenschaft), Jürgen Ehlers, Rudolf Stichweh, Michael Springer (Editor of Spektrum der Wissenschaft

Stichweh: Historians have more or less accepted that the history they recount could also be told differently. There could be completely different versions of Caesar's murder, that are in certain ways equally "true" and convincing. History, as told by historians, is also partly an artistic construction.

Ehlers: Partly, but not entirely!

Stichweh: The scientific tradition constantly puts itself under pressure to try to reach reality. I consider this to be a premise, something people require of themselves. But it is not something that ever really happens.

This premise is particularly strong in certain disciplines such as physics. Mathematicians accept it as obvious that they construct, that they invent; they give a lot more weight to creativity.

Spektrum: *If a number is arbitrarily changed in a physical theory, it has an effect: the theory is no longer correct. A bridge constructed according to that theory would collapse.*

Stichweh: Engineers can build stable bridges from experience, even if the underlying theory is false. I don't see the link between science and engineering as being such a close one. One often builds something based on an incorrect theory, and as long as the bridge remains standing, or as long as the medical treatment works, even if it's wrongly understood, then there's no problem.

Spektrum: *There's a question of terminology we can't get round. What is reality?*

Ehlers: In the end physics has to be able to trace its conclusions back to something simple and directly perceivable. In this respect one can only make sense of reality in

relation to perception, while instruments do let us learn something about things that aren't directly accessible to our senses.

If I see amoebae through a microscope, or the surface of a planet through a telescope then it seems reasonable to me to say, "I can see a real object there. I'm not creating something there purely from my imagination." In everyday life we also say, "I'm convinced that my house is standing there, a real object, even if I can't see it just now." Why does this definition of reality, that is at least extremely practical in everyday life, suddenly become problematic?

Even if two historians argue about Caesar's murder, they both believe that the murder did happen, just that they don't know exactly how. And we physicists would like to know how the planets are made, how the stars radiate their energy: We're talking about natural objects. That seems to me more reasonable than to say that we're talking about modes of communication between particular people.

Stichweh: The concept of what reality is, and how it can be arrived at, has shifted greatly with time. In the eighteenth century there was a great debate, related to the implementation of experiments, about the difference between nature and art.

There is a tradition, that goes back to Goethe, which says that experiments apply a force to nature and that, under these circumstances, nature will never really reveal anything about herself, but rather produce artifacts. At some point though physicists and chemists accepted that it was conceivable that they might reach an approximation of reality using experimental apparatus.

There is also a clear division in the history of twentieth-century elementary particle physics between those experimental traditions that use use optical instruments, photographs and single events and those that use electronic instruments and treat large numbers of events in statistical way. Such traditions have been separate for decades and they dispute one another's claims to reality: The electronic side say, "You've only got one photo, that means absolutely nothing," while the optical side sets much store by the mark of a single particle. So the question of what is real has remained controversial for a long time between the interested physicists.

Ehlers: I don't think one can discuss the understanding of reality in physics without agreeing on what a theory is and and how it relates to experiment—and that has changed somewhat with time, as you said. On the one hand the findings of physics are evaluated internally—that is, we require that a theory produces a logically ordered and mathematically formulated system of theorems. On the other hand we have experiments, for which we also need rules of course. Furthermore, theory and experiment must be made to relate to one another. When the consequences of the theory are—according to these rules—in agreement with experiment, then we physicists say that we have understood something about reality.

You have referred to the fact that those experimental results that are considered correct shift with time. I would claim though that one would only regard a theory as an improvement on an earlier one if not only the newly introduced experiments, but also the old ones, when judged fairly, agreed with the theory.

Spektrum: *Professor Stichweh, would you call that progress, or just the replacement of one story by another?*

Stichweh: I don't think that "progress" is a good description of the development of science. I would put forward an evolutionary picture. If one applies an evolutionary approach to the development of science, then the Darwinist distinction between variation and selection becomes important. Scientists claim to have hit upon something new, something that makes a difference to what was previously believed and observed.

And then these purported innovations either manage to mobilize the power of persuasion, and to establish themselves, or they do not—that is the selection part of the the scientific communication process. It is interesting, as in evolutionary biology, to study the selection environments in which scientific variation either stands its ground, or is eliminated. Then one no longer requires the concept of progress.

Spektrum: *Professor Ehlers, is there progress in science?*

Ehlers: Let's take a piece of metal. With the passing of time we have understood its properties better and better. At first it was described only very crudely, by means of geometry, as a thing with a particular shape. Then it was found that it had a particular weight, and so the new concept of mass was added.

Then we learned how to describe deformation, and we were able to say that it also had elastic properties. Then we discovered optical and electrical aspects. At first we described it crudely, just as it was accessible to our senses. Later we conceived ideas of atomic structure and came up with new experiments to see, for example, how the specific heat and conductivity behave at very low temperatures.

With this sequence of events we learned something about one and the same real entity, namely a lump of metal. It makes no sense to me that we should not be allowed to say, "We're learning more here about a real object with the passing of time!"

Spektrum: *Professor Stichweh, it is, after all, necessary that a theory is correct. That is a theory's "fitness".*

Stichweh: In the 150 years since Darwin another aspect has, to an increasing degree, superseded the environmental selection of organisms in evolution theory: Internal selection mechanisms, which are to a certain extent internal representations of the environment, act before confrontation with the environment occurs.

And I imagine science similarly, as something which uses ever stronger internal selection mechanisms, in place of direct testing in the environment, which is in any case out of reach. And these internal mechanisms are, in fact, all of the concepts that natural science has come up with in its history.

Ehlers: Would you say that a lump of iron only has those characteristics because people have contemplated these concepts? Or wouldn't you find it sensible to say that this iron has always had those characteristics, but that we humans have found out more about them with the passing of time? In everyday life we don't say, "It appears to me as though a chair is standing there," but rather, "A chair is standing there."

Stichweh: I don't dispute it. But when one observes scientists from outside it stands out immediately that whatever a scientist says about anything, another might say something different. As long as something is science, it is also disputable.

Ehlers: There are areas, such as mechanics or the quantum mechanics of atoms and molecules, which will never change. On a certain scale, and for a certain range of energies, quantum mechanics is correct, once and for all, just as Newtonian mechanics is for stars and planets. These are, so to speak, the finished products of science: reliable insights, not just deliberations. How could the moon landings have been managed if Newton's laws didn't embody something real about nature.

Spektrum: *What about objectivity? When scientists consider a theory to be final then they say that it is objective, independent of its inventors. Is this concept of objectivity just a construct of internal scientific discourse? Is it just an ethical norm?*

Stichweh: Objectivity is a professional standard in certain communities. What is mainly meant is that, for example, in biomedical research, it is not the experience of ones own body which should dominate but rather a distanced or "objective" approach. Are there really things, as Professor Ehlers thinks, that we know will always be true? How do you know it?

Perhaps tomorrow there will be a new theory that puts that which we hold today as certain truth about this metal lump in a completely different light, perhaps even refutes it. Some elements of knowledge can remain stable for centuries, and then something happens after all, which shatters them.

Spektrum: *So, there are no "eternal truths"?*

Ehlers: No eternal truths, if we mean by that they cannot be improved in any way. But when it comes to the factual content of Newton's law of gravitation or Galileo's law of free-fall then, to a certain precision, nothing has ever changed.

Spektrum: *Would you nonetheless say, Professor Stichweh, that it is only speculation that the law of free-fall will be valid for all time?*

Stichweh: I find it psychologically plausible that scientists would assume that something that has remained undisputed for a relatively long time, will remain so. But I'm not so sure, because it's exactly the surprises that make science interesting.

Think about the still-raw shock that Darwin caused in the millennia-old tradition of thought on the subject of nature, biology, organisms and their histories. Isn't the physical mechanism of gravitation still an open question? Might there not still be surprises?

Ehlers: I'm quite convinced that, in the future, we'll see the General Theory of Relativity as just an approximation to a better theory. But a new theory will only be accepted if it can reproduce the empirical results of the old. A new theory doesn't establish itself simply because the exponents of the old have died out.

During the transition phase, while people are probing around and don't yet know how to improve the theory, then of course personal convictions and preferences play a substantial role. But in the end the decision is made using criteria on which both sides agree: the representatives of the older and the younger generations.

Stichweh: Is that always the case? I don't know a single opponent of Darwin who became convinced. They actually did die out, some time in the nineteenth century.

Spektrum: *Professor Stichweh, for you, what is the truth in natural science?*

Stichweh: It's a mission statement—a goal that science aspires to in its process of discourse. A scientific statement is true when, in principle, and if sufficient time were allowed for the argument to be made, everyone would be convinced by it. But this mission statement is susceptible to change. In the nineteenth century scientists started to say that they wanted nothing to do with absolute truth because that brought them into competition with religion; they would deal at best with relative truths, with provisional conclusions.

In the twentieth century, according to sociologists of science, ideas such as "truth" don't appear in discussions between practising natural scientists, but rather we see a more ironic, cynical, manipulative language: things like, "Alright, I'll just twist it somehow, so that it fits." I would not go as far as some sociologists who think that, with this, truth has completely disappeared from science. Truth remains the ultimate description of that to which science aspires. It has however, in the sense of everyday reality, increasingly lost its meaning, from the eighteenth century onwards.

Spektrum: *Does natural science produce relative truths that are susceptible to change with time, or truths that are absolute in character, and that differentiate science from other cultural activities?*

Ehlers: The theorems of natural science do not have the character of absolute truth. Physicists work out approximations. However, these approximations are sometimes so reliable that one thinks that one has discovered something important. Whether you call that thing "true" or call it "usable" is really a question of terminology. But, in the face of a critical public, it's important to stress that the the degree of this reliability is independent of the individual to a much greater extent than in any other area of human activity.

Spektrum: *Reliability, usability, usefullness—are these categorisations that we can agree on?*

Stichweh: Reliability is one of those funny things. Modern science, at the end of the twentieth century, has a very strong awareness of uncertainty, of the approximate nature of all knowledge. If, however, you work on climate models, for example, where society has high expectations, where you are expected to make recommendations, to set the priorities of politicians, then you don't show these uncertainties outwardly, but rather try to deliver a relatively clear message.

I wouldn't describe science internally in terms of reliability, but rather as an undertaking which has an ever more clearly articulated consciousness of the provisional nature of its possible statements.

Spektrum: *Would you grant science any special status amongst society's activities?*

Stichweh: If I compare science with art or religion, from outside, then science is different in the sense that it claims that its statements are true. That is, that everyone

should, in principle, be able to agree on those statements. But that is an outsider's description, and this concept of truth is relatively abstract.

Internally to science "truth" is in retreat in many ways, just as artists no longer describe their pictures as "beautiful". We observe this move away from earlier ideals in many areas of society.

Spektrum: *Do scientists grapple internally with their uncertainty in an ironic and cynical manner, but communicate more certainty to the outside world than they feel themselves?*

Ehlers: Of course scientists prefer to publicise things that they think are understood. If they emphasised the others, then the public wouldn't provide them with the necessary funding; it's a practical consideration.

Nevertheless scientific "finished products" do come into being—Heisenberg called them "completed theories"—that are reliable in a given field and that require no further adjustment. Surprises are never ruled out, but the relative degree of certainty is greater in the natural sciences than elsewhere.

Spektrum: *So, Professor Stichweh, a relative certainty, which is never immune from surprises?*

Stichweh: The surprises come from science itself: We don't know what insights science will confront us with tomorrow and which insights, long held true, will subsequently no longer convince us.

The sociologist Niklas Luhmann said that truth is science in a state of exhaustion. From that angle, completed theories and final truths are of no interest at all to science. Science is also critical: Everyone who practises it must reckon with the fact that every argument, no matter how watertight, will come up against objections and criticisms—and it's exactly this that makes it scientific. If we discuss that which nobody doubts at present, then we discuss something that is of no interest to science, because it cannot be called into question.

The questions were asked by Reinhard Breuer and Michael Springer, both from Spektrum der Wissenschaft (the German edition of Scientific American). The interview was held in the year 2001 in Berlin in the offices of the Berlin-Brandenburg Academy of Sciences.