'If I can convince my brother, the rest of the world shouldn't be a problem'

Erik and **Herman Verlinde** on emergent gravity, the cycles of theoretical physics, the increasing number of connections with other fields, and the flood of new experiments. 'When we started, black holes were something very abstract. Now there are actual observations.'

Text: Bruno van Wayenburg

The Verlinde twins are well familiar in Dutch physics. Erik and Herman were born in Woudenberg on 21 January 1962 and shared their interest in the field at an early age. As students and later PhD students under Utrecht professor Gerard 't Hooft, they formed a close-knit club with Robbert Dijkgraaf – currently Minister of Education, Culture, and Science – discussing and focussing on string theory.
Herman Verlinde is now a professor at Princeton University in the United States. Erik Verlinde is a professor at the University of Amsterdam and chair of Delta ITP's Board of Directors. In 2009, he launched a theory of gravity in which thermodynamics, quantum mechanics, and gravity are intertwined in a fundamental way: emergent gravity, based on both the twins' ideas.

Your sparring partner Robbert Dijkgraaf has joined the Cabinet as Minister of Education, Culture, and Science.

Herman Verlinde: 'It happened very quickly, of course, but I thought it was a natural step. He is someone who studies the issues in question from all sides. He was also nearing the end of his time as director of the Institute for Advanced Study, here at Princeton. And he has always remained very involved in the Netherlands.'
Erik Verlinde: 'Actually, I wasn't surprised. I think he is a tremendously strong candidate for such a position and he can contribute a lot. I had emailed him shortly before it happened. I am working on a research project that is very directly related to matrix models that Robbert worked on. I guess it will be difficult for him to respond now.'
Herman: 'Many of the things that the three of us did back in the day are now back at the heart of the research that focusses on how to combine quantum mechanics with gravity. So, I think it would interest him quite a bit.'
Erik: 'The matrix models are a model for what we call emergent gravity. For a century, gravity was described by Einstein roughly as follows: masses deform spacetime, causing objects to move toward heavy objects. We observe this as gravity. Emergent gravity implies that curved spacetime is in turn explained by a deeper, microscopic quantum world, in which quantum entanglement plays a role, the special remote link that connects quantum mechanical particles, and which also plays a crucial role in quantum computers.'

The emergent theory of gravity that Erik put forward in 2009 caused quite a stir, even reaching the pages of the *New York Times*. What is its current status?

Erik: 'That theory built on earlier ideas by Stephen Hawking and Gerard 't Hooft, which had taken a bit of a back seat. They saw connections between black holes and thermodynamics. Black holes have a temperature and entropy, a kind of measure of disorder. I reversed an arrow, as it were: it is not gravity that is the fundamental phenomenon, but it arises from the microscopic quantum world. It is, as they say, emergent. With this, I wanted to give developments a push. Now you see that other people are finally convinced and thinking in the same direction.'
Herman: 'This field often goes through cycles, from searching for new angles to working out certain issues that arise from them.'
Erik: 'This idea has also been around four times, in different forms. But every time we go around, we learn more."

Erik Verlinde


BOB BRONSHOFF

How did you get into physics?

Erik: 'As high school students in the 1970s, Herman and I became hugely motivated by the television broadcast *The Key to the Universe*, by science writer Nigel Calder. We borrowed books from the library, which we discussed a lot, also with our older brother. Unfortunately, he passed away five years ago. He was more interested in astronomy, whereas the two of us found these kinds of fundamental questions fascinating to discuss.'

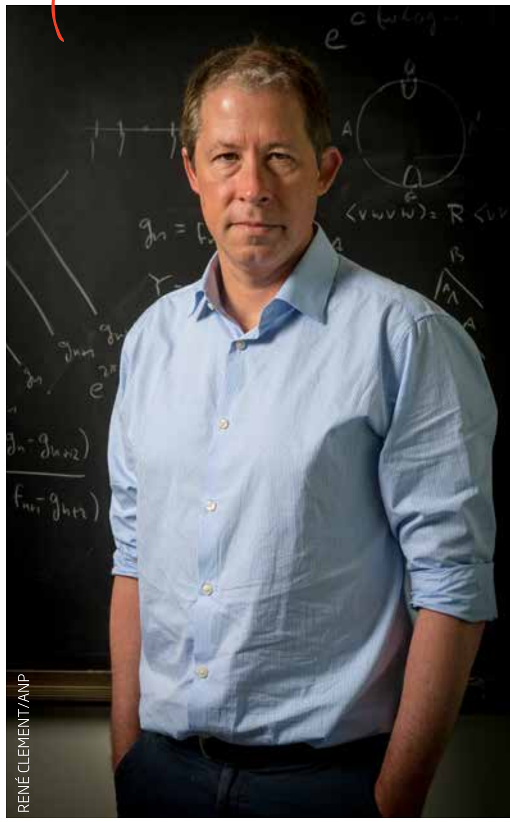
And you never really stopped.

Herman: 'Yes, we'll continue doing so after this interview. Then we'll see how long we can agree with each other (laughs).'
Erik: 'I often think: if I can convince my brother, the rest of the world shouldn't be a problem. But seriously, we were pretty lucky with the people we met during our PhDs in Utrecht, like Robbert. We discussed endlessly and published about it ourselves, which was quite unusual.'
Herman: 'Often, one of us would come up with the original idea and then the other two would start working on it.'
Erik: 'The idea would bounce between us, and we would work it out together in a kind of relay.'

After your PhD, you both left for Princeton University to join one of the top groups in the field of string theory. Erik, what brought you back to the Netherlands in 2003?

Erik: 'That was for personal reasons, but there was also the idea that we could set up a good string theory group in the Netherlands. Physicist Sander Bais had the original idea, but I threw myself into it as well, with Robbert and Jan de Boer. By now, the group has grown tremendously, with many visitors and influx of foreign guests. I think the group is somewhere in the top five in its field, after Harvard and Princeton.'
Herman: 'In Europe, I think Amsterdam is the most established string theory group.'

Herman Verlinde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Erik: 'Setting up Delta ITP was a logical extension of that. At the time, we saw that with Amsterdam, Leiden, and Utrecht joined together, we could form a kind of nucleus to grow research lines and attract talent. In the developments of the past decade, there are more and more connections with other fields, such as quantum information, cosmology, but also, for example, life sciences. At the same time, we have the first-ever observations of black holes: the detection of gravitational waves by LIGO and the picture of the black hole in the M87 galaxy. When we started out, black holes were something very abstract; now there are actual observations.
The question, of course, is always whether the theories we work on can predict something measurable. That's why these developments are very interesting: can we make connections with possible observations? So much information is being released now, also thanks to all kinds of new satellites, such as the James Webb Space Telescope.... As theorists, we have to take advantage of this. I hope and expect that it will result in a huge turnaround.' ■