Player in a **Magical World**

What do soccer and quantum mechanics have in common? Both have surprising twists in store that are difficult to predict. Soccer, however, at least follows some rules that are more or less reliable. As a striker, **Jens Hjörleifur Bárðarson** controls the ball; as a physicist, he masters the rules of the quantum universe. The 35-year-old researcher at the **Max Planck Institute for the Physics of Complex Systems** in Dresden studies atomic particles, which display many a tricky move.

TEXT **ALEXANDER STIRN**

When Jens Hjörleifur Bárðarson has possession of the ball, the opposing team needs to be on guard. The striker for the second team at the Sportfreunde 01 Dresden Nord sports club was one of the mainstays of the success this amateur soccer team notched up last year. It was Bárðarson's first season with his new team, and the Sportfreunde moved up a league – from Dresden's City League B to City League A.

The nimble Icelander couldn't have had a better start. "I enjoy the competition," says Bárðarson, grinning and running his fingers through his thick beard. Things aren't going that well this year, though. After 19 games, the statistics of Saxony's soccer association show just three goals, and Bárðarson is starting to brood.

But when Jens Hjörleifur Bárðarson has the ball, things also get complicated – off the field at least, in a spartanly furnished office at the Max Planck Institute for the Physics of Complex Systems in Dresden. For the past two years, the theorist has headed a research group here that investigates quantum matter: electrons and other particles that often develop extremely tricky moves at low temperatures.

IDEAS THAT TIE THE BRAIN IN KNOTS

"It is true that many physical effects can be understood by simply treating electrons as balls that move from one point to another," says Bárðarson. One example of this is electrical conduction in a conventional wire, where the electrons flow in at one end and are pushed out the other. "But things get really interesting when we realize that electrons are actually waves," says the theorist.

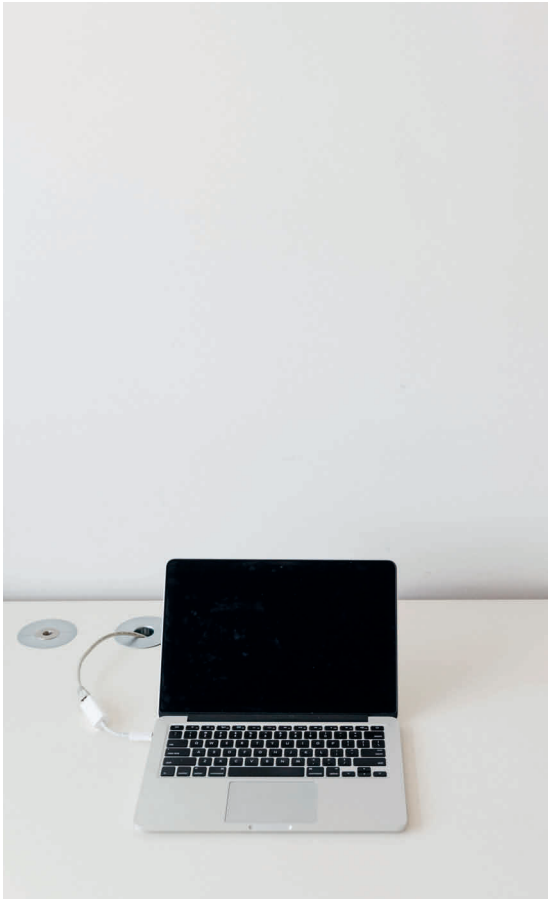
This is when strange things happen: like light, the particles can superimpose on each other and produce unforeseen effects. They can even exert an influence from a distance. Physicists refer to this principle as entanglement. It's as if the equipment manager at the edge of the field were to let the air out of a ball, causing the game ball to deflate just before the striker intended to shoot.

Albert Einstein once called this "spooky." Bárðarson's work is even spookier. "Topological insulators," for example – one of the fields of research the Icelander is diligently working on in Dresden – conduct no current in their interior. However, the waves of the electrons knot together on the surface. From a physics point of view, the mess can be sorted out only when the insulators become conductors at precisely these points.

These are ideas that can tie the brain in knots just listening to them. Bárðarson likes this. "My undergraduate studies included an excellent lecture on quantum mechanics," explains

Staying on the ball: Jens Hjörleifur Bárðarson was a passionate soccer player even as a child. He finds analogies to his sport in physics, too – for example when electrons behave like balls.

Photos: Sven Doering



Left: Jens Hjörleifur Bárðarson can concentrate on the essentials at his desk, which is completely free of paper. This allows him an unobstructed view of the physical problems he works out on the computer.

Right: Jens Bárðarson, Jan Behrends, Talía Lezama and Soumya Bera (from left) develop the occasional idea as a team.

the 35-year-old. "To solve the problems we were assigned, I often had to sit in the library for days. This was one of the most exciting courses I ever attended."

The fun and the fascination have retained their hold on him ever since: "Quantum mechanics is a bit magical – it contradicts all intuition," says Bárðarson. In a nutshell: it's a challenge, and the Icelander likes challenges: "For me, being a physicist doesn't mean simply being able to calculate things. It means developing an intuition for what will happen."

And what could be more fascinating than doing this in a field with completely unimaginable rules? "When I kick a ball, it's not particularly difficult to calculate what will happen – but it's not particularly interesting, either," says the recreational soccer player. Quantum mechanics is different. "Here, I can't rely on things I learned as a child. That's magic."

Jens Hjörleifur Bárðarson learned about the real world in Selfoss – the largest town in southern Iceland, with around 5,000 inhabitants. This is where he first saw the light of the world in 1979, as one of five children. His mother was an insurance broker, his father head of the municipal planning authority. At home, there was never any talk of him also becoming a civil servant. "Even if my father had wanted this – which I don't believe he did – he wouldn't have said anything," recalls Bárðarson. "At home we were always allowed and encouraged to follow our own goals and make our own mistakes – that's how one grows up."

When Bárðarson wasn't playing soccer, he was reading. There's hardly a photo of him as a child where he doesn't have a book in his hand. "I read everything I could get my hands on, I always wanted to learn something new," says the researcher. "At high school, I even enjoyed my German lessons, which weren't always the most popular among my classmates."

PHYSICS OLYMPIAN ON THE NATIONAL TEAM

Mathematics, physics, IT, or maybe even engineering? Bárðarson found it difficult to choose the right subject to study. Since most of his friends were computer nerds, he himself also tended toward computer science. But the decision was clinched by the International Physics Olympiad, a global competition that also included students from his school in Selfoss. One of his teachers urged Bárðarson to take part, so he prepared for the competition as one of the few Olympians. "Whatever I do, I take it seriously – I'm ambitious about things like that," says the Icelander. As if to back this up, he adds: "In physics, I now compete only against myself. I compete with others when I play soccer."

And the training paid off. Bárðarson secured a spot in the Icelandic national team that was to represent the island in the final round of the 1999 Olympiad in Padua, Italy. The preparations included work experience in the form of a short internship in a faculty of physics. One of the professors explained to Bárðarson that if he were to study physics, the queen of all disciplines, he could still transfer to engineering, if necessary, but not the other way around. "That sounded convincing," says Bárðarson. "I believed him."

There was no Olympic victory, but his physics studies proved to be the door to success. Bárðarson enrolled at the University of Iceland in Reykjavik, then the only physics faculty on the island. He – as well as a fellow student – achieved the best grade awarded to date for their bachelor studies. And following the ancient Icelandic tradition, he went out into the big, wide world. "One of our Viking sayings is: 'Those who grow up only at home remain dumb.' Those who spend time only

Photo: Sven Doering

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with the people in their own surroundings come up with no new ideas, no fresh impetus."

Jens Hjörleifur Bárðarson went on to study in Denmark and Sweden, completed his Ph.D. in Leiden, the Netherlands, spent several months in Berlin, and began the postdoc phase of his career at Cornell University in New York. Finally, he was drawn to Berkeley, to the California sun. His future boss tempted him with the words: "A postdoc is probably the last chance in your career to learn something completely new."

Bárðarson grins at the thought. "That was exactly what I wanted to hear," he says. "One of my main goals is to learn new things." The individual electrons with their strange, often knotted waves were then joined by entangled particle collectives that exert a mutual effect as if via an invisible hand. "I was very happy there."

Now Dresden is his playground. "The cycle of an academic career is such that it's not always possible to choose where you work, and it's difficult to put down roots somewhere," says Bárðarson. Researchers and soccer players are very similar in this respect: in order to advance your professional career, the dream teams with globally recognized names and famous players are often not the best choice – or they are simply out of reach.

EXPERIMENTS TO BREAK OUT OF THE WORLD OF IDEAS

Bárðarson, a Manchester United fan, is well aware of this. And he accepts it, especially since Dresden was anything but an emergency solution. The Icelander has progressed from postdoc to Group Leader. "What's more, the Max Planck Institute in Dresden is one of the most respected institutes in the world in my field," he says. Almost every expert pays a visit to Dresden once a year. And it doesn't hurt that there are experimentalists working on related things just across the street, in the Leibniz Institute for Solid State and Materials Research.

Even though Bárðarson strongly emphasizes that he considers himself to be a theorist, he doesn't want to conduct his research all alone in a world of ideas. "The work wouldn't be any fun if there were no reality against which my calculations could be compared," says the Icelander. "As a theorist, you naturally try to achieve as much as possible with pen and paper. But for me, it's important to remain close to experiments – without being restricted by them."

It's the freedom of the theorist: Bárðarson always starts with a physical question – an idea devised and solved with equations that work only in a greatly simplified model world. The next step is computer simulation. This takes into account all the disturbances – caused by reality – that would make a manual calculation impossible.

"I prefer to call it a computer experiment rather than a simulation. It's often necessary to develop completely new techniques," says Bárðarson. The physicist wanted to use one of these numerical experiments to gain a better understanding of topological superconductors – materials in a state in which they conduct current in their interior with no resistance, and for which calculations indicate that they accommodate as yet undetected elementary particles on their surface. In this environment, Bárðarson sought to simu-

late, for instance, the motion of a single massless particle. The conventional method involves chopping up space into tiny pieces in which the equations of motion of the particles can be solved numerically. In the case of the massless particle, however, a second particle suddenly appeared, ruining all of the calculations.

After numerous attempts, Bárðarson decided to take the momentum of the electron, rather than its position, as the basis for the simulation, and was surprised to find that everything went according to plan: "Research always includes a little bit of luck. In the end, it comes down to trying things out – and hoping for the best."

The acid test is then waiting on the other side of the street. This is where the experimenters subject wires, for example, to a magnetic field, measure the strength of the current, determine how it depends on the temperature, and compare the results with the theoretical predictions. Bárðarson isn't necessarily after a confirmation here – quite the opposite: "It's often much more fun to obtain measurement results that are surprising and not in agreement with your own predictions, because this is precisely what paves the way for something new." But for him, the details of everything his colleagues do is "black magic." The theorist laughs. "I understand the words that describe the experiments, but that's about it."

LONG DETOURS FOR A GOOD CUP OF COFFEE

So was it worth moving from Berkeley to the banks of the Elbe River? "Yes, absolutely, even though, as a matter of principle, I refuse to compare cities," says the 35-year-old, "because it's very easy to pick out the best things about one city and compare them with the worst parts of another. This can only end unfairly."

With incidents like the anti-Islam demonstrations, Dresden hasn't made it easy for foreign researchers to move to the city – or to the federal state of Saxony. As a young, politically aware student, he was unable to imagine himself ever going to work in the US – a gesture of protest against American foreign policy, and the reason he did his doctoral work in the Netherlands.

But then he actually did find himself crossing the Atlantic – and he liked it there. "It's generally not a good idea to judge things from a distance, because everything turns out to be very different when you are actually there," says the young scientist. "I now try to do that as seldom as possible, but I know I'm not perfect."

So Bárðarson is quite happy in Dresden. And the issue with coffee has also been sorted out. It took at least a month before the researcher, a self-confessed caffeine fan, finally found a coffee house he considered to be acceptable. "I'm prepared to go out of my way for a good cup of coffee. And what's more, I enjoy walking," he reveals. "Lots of people think I'm nuts simply because I'm prepared to take a 30-minute detour for a cup of coffee."

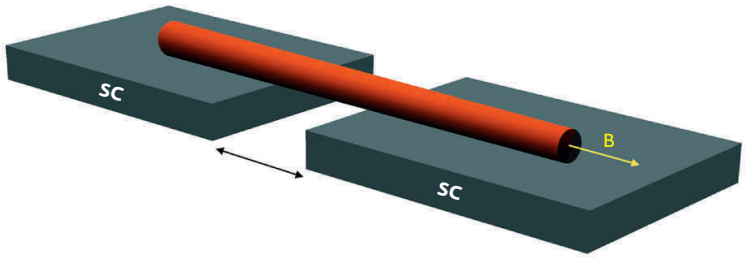
His passion has twice rewarded him with a special scientific job: In both Leiden and Berlin, Bárðarson was tasked with finding a coffee machine for his institute. He did some research, compared, tested, did more research, and finally came up with a solution that convinced everybody. As Bárðarson describes what he did, it's as if he were describing his doctoral thesis.

It's the same ambition the 35-year-old applies to every task he tackles –

Photo: Sven Doering

Left: Jens Hjörleifur Bárðarson does a lot of thinking in the library. He loves immersing himself in his books.

Right: Bárðarson and his colleagues proposed an experiment to detect and characterize Majorana fermions, a type of elementary particle that has as yet been described only theoretically. These could occur when the nanowire of a topological insulator – a material that is electrically conducting on its surface and insulating in its interior – is combined with a superconductor (SC) – that is, a zero-resistance conductor – and penetrated by a magnetic field (B) of a certain strength.



from research to soccer to learning German. "I think it's important to speak the local language in a foreign country – not least so that I can order my coffee in German," he says. The institute is no help at all in this respect; most of his colleagues speak English. And the couple of words of German that Bárðarson learned out of curiosity in high school were replaced by similar-sounding Dutch while he was doing his doctorate. "In the beginning, I often unwittingly spoke to people in Dresden in Dutch, because I thought I was using the correct expressions. They looked at me like I was crazy," he says.

Bárðarson decided to take a crash course. Four weeks, five days a week, four hours and fifteen minutes per day, he estimates. Every day begins at eight o'clock, a further challenge for the late riser. He struggles out of bed, takes a half-hour walk to his coffee house, orders a croissant and a cappuccino, goes to his German course, then drags himself to the institute. "Before those four weeks, I used to ask people whether they spoke English. Now I tell them that my German is bad," he says. That's a massive understatement.

His only problem now is with the dialect in Saxony, which the players from Sportfreunde 01 Dresden Nord also bandy about. "I simply deal with it as a completely different language," he says with a grin. His command of the dialect now is at least enough for him to understand the coach – and to shoot goals.

"I don't usually do things half-way," says Bárðarson. "When I take up something new, I learn it as well as I can, then I dig deeper and deeper – just as I do in my research." This also applies to his latest hobby: Bárðarson has started to learn to play the ukulele, the Hawaiian mini-guitar played by plucking its strings.

ICELANDIC HERITAGE: A PENCHANT FOR DARK TUNES

"I somehow always wanted to make music, although I spent most of my time as a child playing soccer," he says. Hence the ukulele, which – he was assured – was particularly easy to learn. True? "For one thing, the chords are easier than for the guitar, and since the instrument is much smaller, you don't have to tie your fingers in knots as you play, either. At least it's not difficult to coax some sort of sounds out of it," says the self-taught musician, grinning. Besides, the ukulele is a happy instrument – it sounds cheerful and lightens the mood.

The other music that Bárðarson listens to, however, doesn't always have this effect. Leonard Cohen, Tom Waits and Nick Cave, for example – great melancholic singer-songwriters and poets, none of whom can be accused of singing cheerful ukulele songs. Cave, in particular, whose music is often dark, impresses Bárðarson. "Perhaps because it harmonizes well with the Icelandic mentality," he says. "The land is usually dark, our sagas are dark, Icelandic humor is jet black. Maybe this rubs off on the soul. I like that."

Bárðarson also listens to music when he's cooking, which is another major hobby. He has just taught himself how to braise – from a book, of course. Next on the agenda is roasting. The theorist already scoured the whole of Dresden for a roasting pan that meets with his approval. He finally found what he was looking for in Berlin. Now nothing can stand in the way of his roasting adventure.

At the same time, Bárðarson is trying out yoga and meditation. He has yet to find the right place in Dresden, but he has already bought the right books.

Anyone who constantly tries out new things and constantly looks for new inspiration also has to be able to let go of the old. Soccer, of all things – his passion since his earliest youth – could soon fall victim to this. "At 35, it's time to start thinking about retiring from soccer," says Bárðarson. And he's not joking, for a change. All too often, he's on the go for his job on match days. Also the age difference in the team is too great, and he has scored too few goals recently.

Nevertheless, he's still got the small balls from his equations and his calculations, even if they aren't really balls at all. But – like Jens Hjörleifur Bárðarson – they're always good for something new, always good for a surprise. ◂

Graphic: Jens H. Bárðarson – MPI for the Physics of Complex Systems