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The Quantum Challenges of the Future

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Between revolutionary applications and theoretical problems still unresolved, quantum mechanics is running fast towards new ambitious goals. Above all, quantum computers

It's now been over a hundred years since **Max Planck** and **Albert Einstein** laid the foundations of quantum mechanics, one of the most revolutionary and controversial theories of modern science. Along a path at the same time tortuous and exciting, which involved some of the greatest minds of the twentieth century's physics (in addition to the already mentioned Planck and Einstein, also **Niels Bohr, Werner Heisenberg and Erwin Schrödinger** deserve to be quoted), the theory took shape slowly in the early decades of the twentieth century, until it reached a first official recognition in the historic Solvay conference of Brussels, in 1927, which saw the presence of the most prominent physicists in the world.

Even if some controversial theoretical issues are still open – including for example the so-called " measurement problem" – which led Einstein to take his distance from it (his sentence "**God does not play dice**" referring to the intrinsically probabilistic character of the theory, became famous), quantum mechanics has then obtained over the years, starting from the second half of the twentieth century, has been **confirmed experimentally** countless times. And its applications soon spilt, from the physics laboratories, over even to our homes: just think, to cite just one example, about modern **transistors** in electronic devices.

Applications that promise to become even more revolutionary and of strong impact in the near future, as **Paolo Mataloni**, professor of quantum optics at the Sapienza University of Rome pointed out speaking on July 5 at the launch event of the Quantum @ Trento project: "There are many quantum technologies that are bound to have important effects on our real life. Among these, I will mention three: the development of a quantum network of sensing devices that allow monitoring of people's **health**, satellite communications and especially **quantum computers** ». The latter in particular has long been considered a sort of **Holy Grail** for many insiders but not only for them: based on the so-called **qubits**, quantum information units, quantum computers are able to process information at a **speed** absolutely unimaginable compared to the most powerful "classic" supercomputer available today. But how long will it take before quantum computers become a reality? "Efficient quantum simulators will be implemented shortly," Mataloni added.

“However, getting to integrate such technology in commonly used computers is another story, which will entail facing **technological hurdles** that are not trivial: we will be talking about that in a few decades».

Another delicate aspect concerning the present but above all the future of quantum mechanics, also in relation to its possible applications, is to establish the exact **boundaries** between the classical and the quantum world. In fact, the laws of quantum mechanics apply to systems on the **microscopic scale**, like atoms and subnuclear particles, but up to what size are quantum effects significant and detectable? Recent experimental research has moved those boundaries in a stunning way, having these effects been observed also in **relatively big** molecules. This is an extremely relevant aspect for applications: technological hurdles, in fact, tend to decrease with increased system size. “At this time, it is hard to make predictions about when we could get there,” Mataloni recalls again. «It is clear that at some point a limit must emerge: for instance, a purely quantum phenomenon like **teleportation**, which is already possible with photons and atoms, will never be feasible with complex organisms like humans. But, besides that, it is still an unknown land, to be discovered”.

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