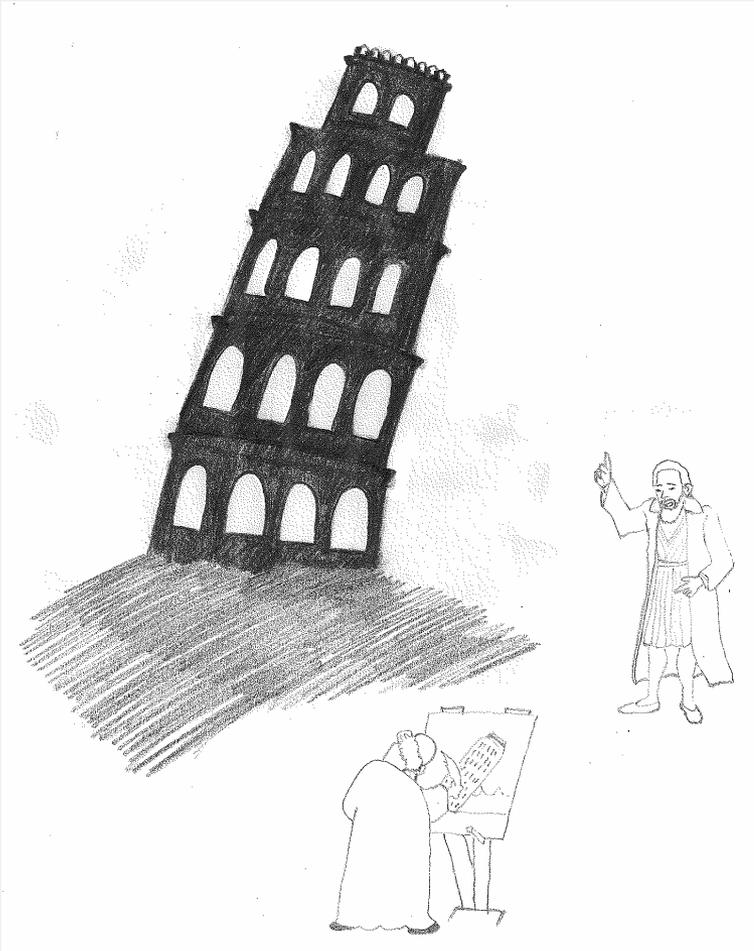


Fundamental Problems in Quantum Physics

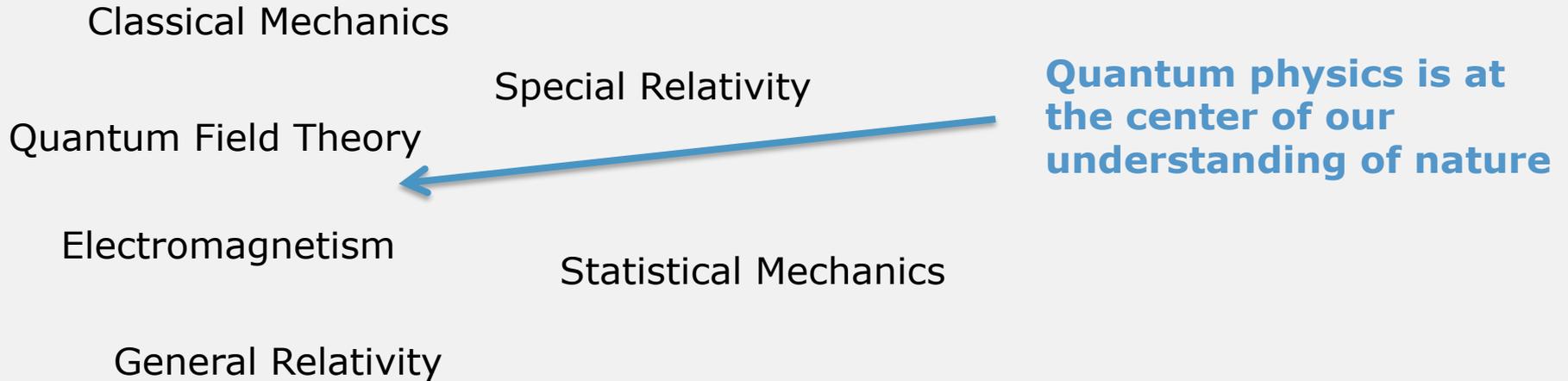


"They should not have saved the money on the foundations"

COST Action MP1006
www.equantum.eu

Angelo Bassi
Department of Physics, University of Trieste
INFN – Trieste Section
www.qmts.it

Why quantum foundations



But the precise meaning of the theory is not yet clear



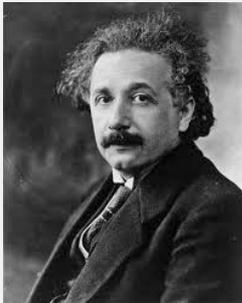
From foundations to technology

Electromagnetism → Radio, TV

General Relativity → GPS

Quantum Mechanics → Semiconductor devices (computer), laser, STM, ...

1935



EPR

1964

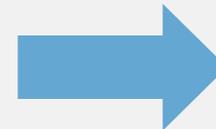


Bell's inequalities

1981

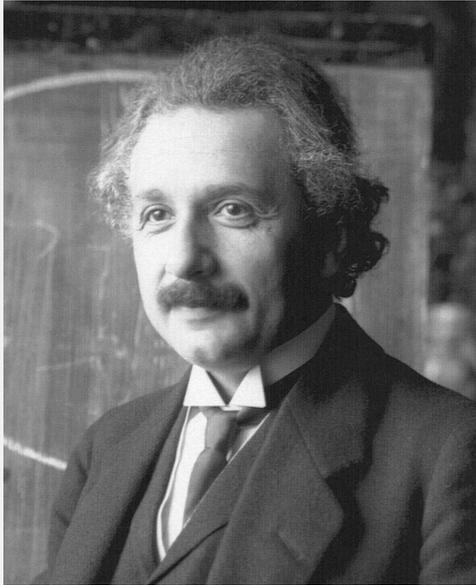


**Nonlocality
experiment**



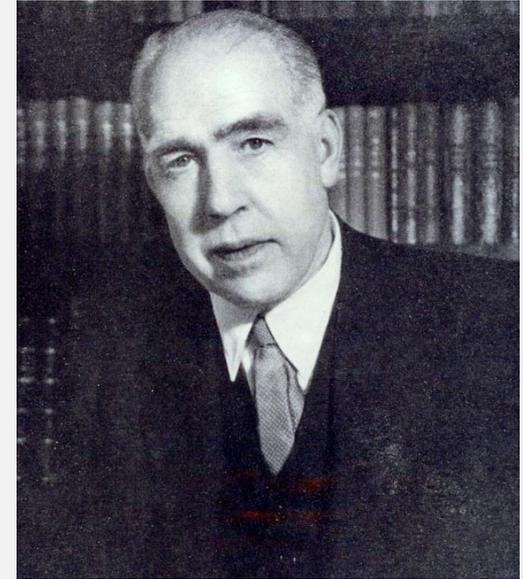
**New Quantum
Technologies!**

1. Quantum theory without observers



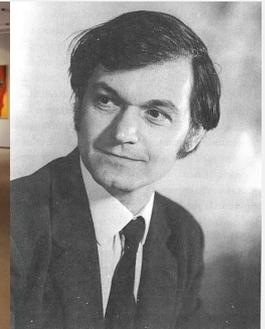
EINSTEIN vs BOHR

What is the theory about?

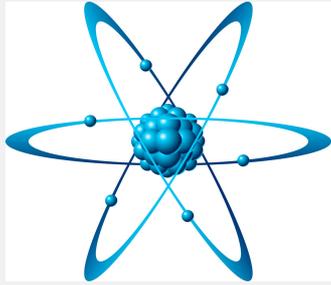


«It would seem that the theory is exclusively concerned about 'results of measurements', and has nothing to say about anything else. What exactly qualifies some physical systems to play the role of 'measurer'? Was the wave function of the world waiting to jump for thousands of millions of years until a single-celled living creature appeared? Or did it have to wait a little longer, for some better qualified system ... with a Ph.D.?»

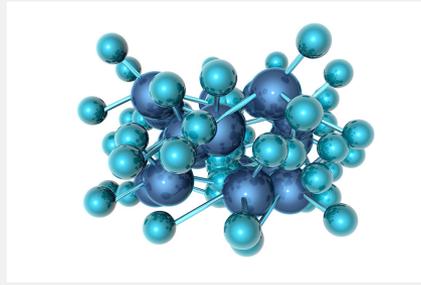
J.S. Bell, "Against Measurement", Physics Today – August 1990.



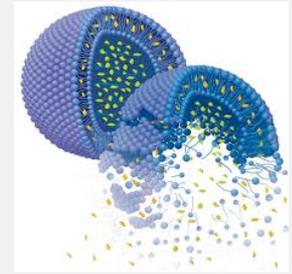
2. Effective description of complex systems



Quantum



Quantum/classical



Classical?

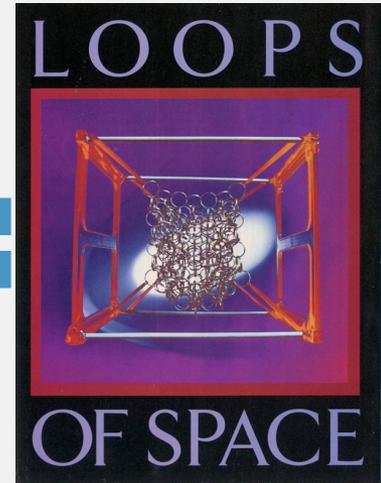
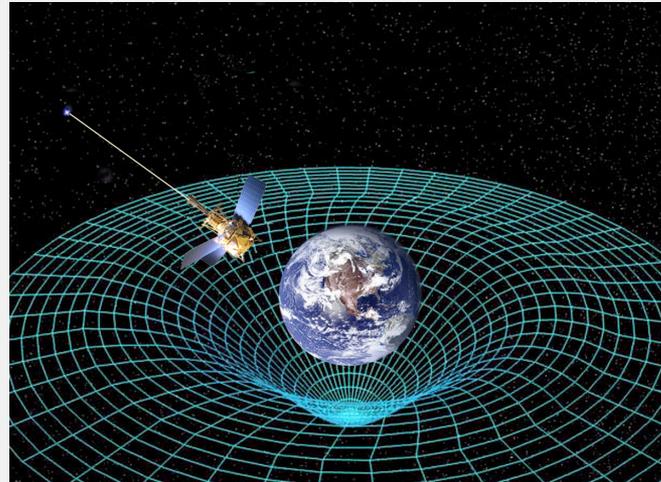
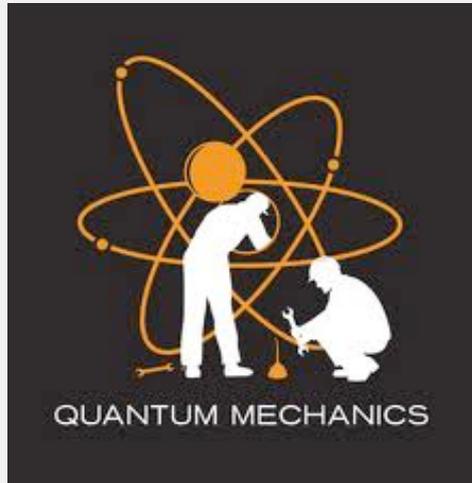
How does the quantum-to-classical transition occur?

Which systems behave truly quantum mechanically, which classically?

Can quantum properties be protected against external influences?

All future emergent quantum technologies (information, communication, sensing, metrology, energy transfer) depend on this!

3. Quantum theory meets relativity



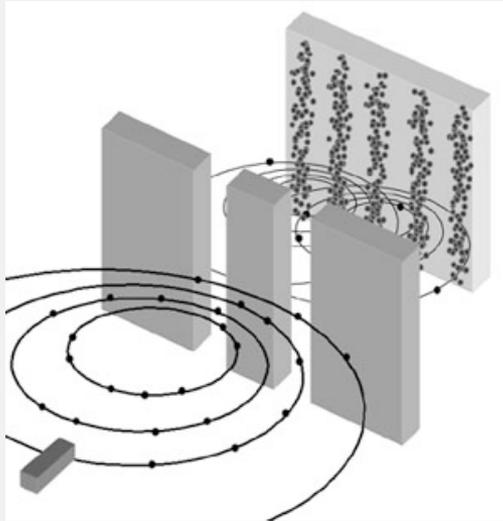
Not so easy!

There is an unresolved tension between quantum theory and relativity

Quantum theory is nonlocal (Bell inequalities)

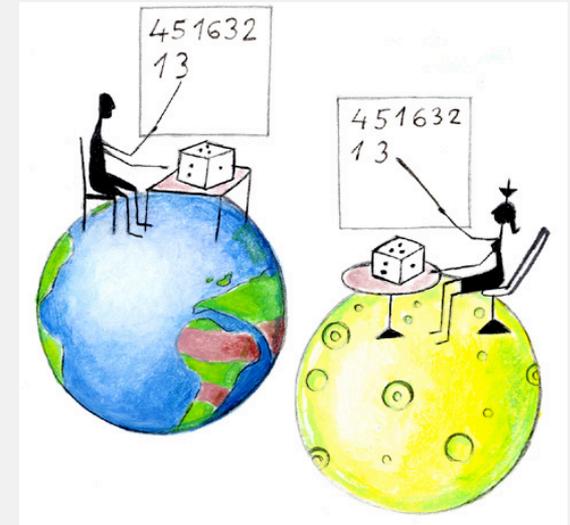
Relativity demands locality

4. From Theory to Experiments



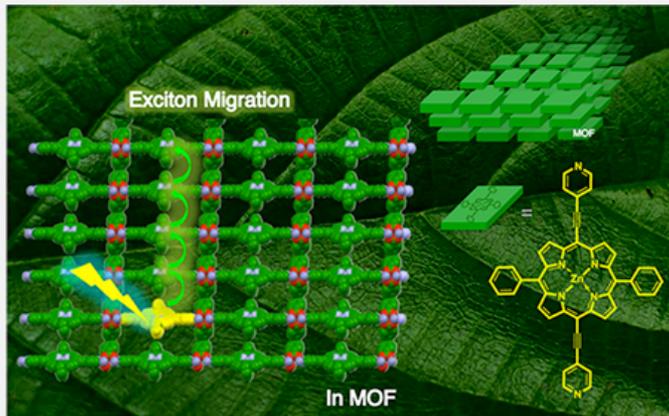
Macroscopic quantum superpositions

Is quantum theory right at the macro-scale?



Quantum non-locality and entanglement

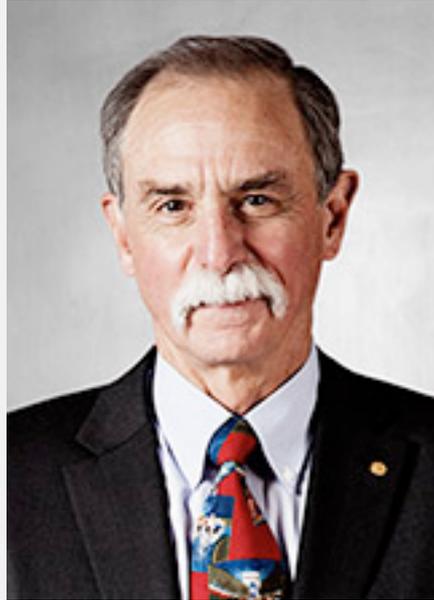
How to exploit quantum mechanics for future information and communication technologies



Quantum effects in light harvesting

How to exploit quantum mechanics for future energy production

Quantum Mechanics



Nobel Prize in Physics 2012

S. Haroche & D.J. Wineland

The Nobel Laureates have opened the door to a new era of experimentation with **quantum physics by demonstrating the direct observation of individual quantum particles without destroying them.** For single particles of light or matter the laws of classical physics cease to apply and quantum physics takes over. But single particles are not easily isolated from their surrounding environment and they lose their mysterious quantum properties as soon as they interact with the outside world. **Thus many seemingly bizarre phenomena predicted by quantum physics could not be directly observed, and researchers could only carry out thought experiments that might in principle manifest these bizarre phenomena.**