



TEQ leads the quest for understanding the foundations of physics



The stadium is fully silent in anticipation: the goalkeeper is ready to dive and catch the ball that the opponent player is about kicking from the penalty spot. The referee whistles, the player hits the ball straight to the goalkeeper, who smiles for the easy catch, but something weird happens: the ball passes both to his right AND to his left

and ends in the net accompanied by the roar of the supporters.

Impossible? Not if the ball is a small, microscopic particle such as an atom or an electron. In fact, the microscopic world eludes the laws of physics established by Newton, which successfully describe the vast majority of the phenomena and events that occur in our daily life, and obey the counter-intuitive, seemingly magic rules of quantum mechanics.

Quantum mechanics is a mathematical framework established at the beginning of the last Century that provides, to date, the most accurate understanding of the results of experiments conducted on physical systems as small as single atoms, very small molecules, and very faint light. The success of quantum mechanics is striking and has driven considerable scientific endeavours aimed at investigating the minuscule effects that are at the basis of very important processes of vast applications, from nuclear

magnetic resonance to the transistor, from the laser to the most accurate GPS.

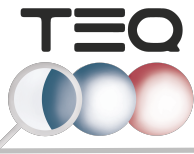
Besides being undeniably successful, quantum mechanics is equally undeniably 'weird'. It allows as perfectly legitimate physical processes that put one of the microscopic systems mentioned above in two different, perfectly distinguishable configurations at the same time! That is, our microscopic foot-ball could pass on the left of the goalkeeper and on his right at the same time. The law that makes such a case possible is the so-called 'quantum superposition principle' (QSP), arguably the most fundamental statement in quantum physics.

The validity of QSP at the microscopic level has been confirmed by an enormous amount of very accurate experimental data: atoms, electrons, and photons (the quantum mechanical building blocks of light) have been prepared in states that superimpose fully distinct physical configurations, such as being 'here' and 'there', at the same time.

However, is this valid only when we consider such elementary quantum systems? Everyday experience seems to suggest so: the foot-ball always slips either on the left or on the right of the keeper (but sometimes he catches it): never in both ways simultaneously. The macroscopic world that is before our very own eyes seems to elude the richness of quantum superposition states. On the other hand, real foot-balls are made of atoms, which are quantum. So why don't we see them behaving quantum mechanically? It could simply be that such states are fragile, or in general hard to see but there nevertheless for us to explore them.

Whether we can observe quantum superpositions of macroscopic objects is arguably 'the' open question in quantum physics. An answer in the positive will boost the quest for the use of the weirdness of quantum mechanics in a much larger set of physical systems, not restricted to the microscopic world. The relevance of this difficult question cannot be remarked enough.

Now, a team of quantum scientists have joined in consortium to address such a fundamental quest from an innovative standpoint, supported by a € 4.4M grant awarded by the European Commission (EC). The Collaborative Project "TEQ" (Testing the large-scale limit of quantum mechanics) puts together 8 leading European research group and company MSquared to explore quantum effects at the large scale under the support of the EC Horizon2020 research framework programme. The project is one of only 26



funded proposals out of 374 submitted to the latest call for Future and Emerging Technologies projects.

The team will levitate a small particle within a well-controlled environment, with low temperature and low vibrations. In such an environment an indirect test of the QSP can be performed by analyzing carefully the noise that affects the center of mass motion of the trapped particle. The measured noise will then be compared to theoretical predictions from different models - some of which assume a breakdown of QSP.

The ambition of the project is to establish the ultimate bounds to the validity of the quantum framework, if any. "This is the question to address", says Prof. Angelo Bassi, PI of TEQ, "because it has been discussed for ages in the foundations of physics community and we now have the experimental tools to get a definite answer. So we really can make a big step forward here."

The award of such a competitive grant reinforces the relevance of fundamental investigations on quantum theory to underpin the current developments in the area of quantum technologies.

TEQ Consortium

University of Trieste (PI) – Italy

Aarhus Universitet – Denmark

Istituto Nazionale di Fisica Nucleare – Italy

Oesterreichische Akademie Der Wissenschaften – Austria

The Queen's University Belfast – United Kingdom

Technische Universiteit Delft – The Netherlands

University College London – United Kingdom

University of Southampton – United Kingdom

M-Squared Lasers Limited – United Kingdom

Photo Credit: Giorgia Perich - Liceo Scientifico "G. Galilei" in Trieste (Italy).

The picture is part of a collaborative project between the University of Trieste and the Liceo Scientifico "G. Galilei" in Trieste.