this page is a blank one

this page is a (n almost) blank one

Invocación

- Among the maxims on Lord Naoshige’s wall, there was this one: "Matters of great concern should be treated lightly." Master Ittei commented, "Matters of small concern should be treated seriously."
- “There is a difference between a blurred or unfocused photograph and a shot of clouds and mist” (Erwin Schrödinger, 1935 Naturwissenschaften 23 807, acerca de la superposición de estados macroscópicos)
- Richard Feynman put it in memorable words: “Nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical, and by golly it’s a wonderful problem, because it doesn’t look so easy”.
- “Practice, therefore, solved after its own fashion the problem of the relations between mechanical motion and heat. It had, to begin with, converted the first into the second, and then it converted the second into the first. But how did matters stand in regard to theory?”, Friedrich Engels, *Dialectics of Nature*, KARL MARX FREDERICK ENGELS COLLECTED WORKS, Volume 25, International Publishers, New York

Invocación

- Among the maxims on Lord Naoshige’s wall, there was this one: "Matters of great concern should be treated lightly." Master Ittei commented, "Matters of small concern should be treated seriously."
- “There is a difference between a blurred or unfocused photograph and a shot of clouds and mist” (Erwin Schrödinger, 1935 Naturwissenschaften 23 807, acerca de la superposición de estados macroscópicos)
- Richard Feynman put it in memorable words: “Nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical, and by golly it’s a wonderful problem, because it doesn’t look so easy”.
- “Practice, therefore, solved after its own fashion the problem of the relations between mechanical motion and heat. It had, to begin with, converted the first into the second, and then it converted the second into the first. But how did matters stand in regard to theory?”, Friedrich Engels, *Dialectics of Nature*, KARL MARX FREDERICK ENGELS COLLECTED WORKS, Volume 25, International Publishers, New York

Invocación

- Among the maxims on Lord Naoshige's wall, there was this one: "Matters of great concern should be treated lightly." Master Ittei commented, "Matters of small concern should be treated seriously."
- "There is a difference between a blurred or unfocused photograph and a shot of clouds and mist" (Erwin Schrödinger, 1935 Naturwissenschaften 23 807, acerca de la superposición de estados macroscópicos)
- Richard Feynman put it in memorable words: "Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy".
- "Practice, therefore, solved after its own fashion the problem of the relations between mechanical motion and heat. It had, to begin with, converted the first into the second, and then it converted the second into the first. But how did matters stand in regard to theory?", Friedrich Engels, *Dialectics of Nature*, KARL MARX FREDERICK ENGELS COLLECTED WORKS, Volume 25, International Publishers, New York

Invocación

- Among the maxims on Lord Naoshige's wall, there was this one: "Matters of great concern should be treated lightly." Master Ittei commented, "Matters of small concern should be treated seriously."
- "There is a difference between a blurred or unfocused photograph and a shot of clouds and mist" (Erwin Schrödinger, 1935 Naturwissenschaften 23 807, acerca de la superposición de estados macroscópicos)
- Richard Feynman put it in memorable words: "Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy".
- "Practice, therefore, solved after its own fashion the problem of the relations between mechanical motion and heat. It had, to begin with, converted the first into the second, and then it converted the second into the first. But how did matters stand in regard to theory?", Friedrich Engels, *Dialectics of Nature*, KARL MARX FREDERICK ENGELS COLLECTED WORKS, Volume 25, International Publishers, New York

Testeando los limites de la Mecánica Cuántica

Omar Osenda

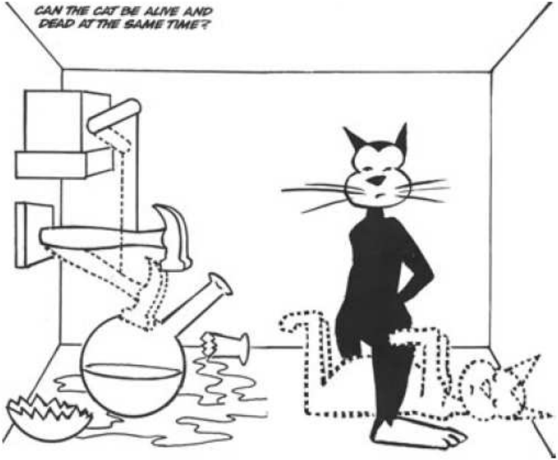
Facultad de Matemática, Astronomía y Física
Universidad Nacional de Córdoba

19 de Septiembre de 2014

Motivación

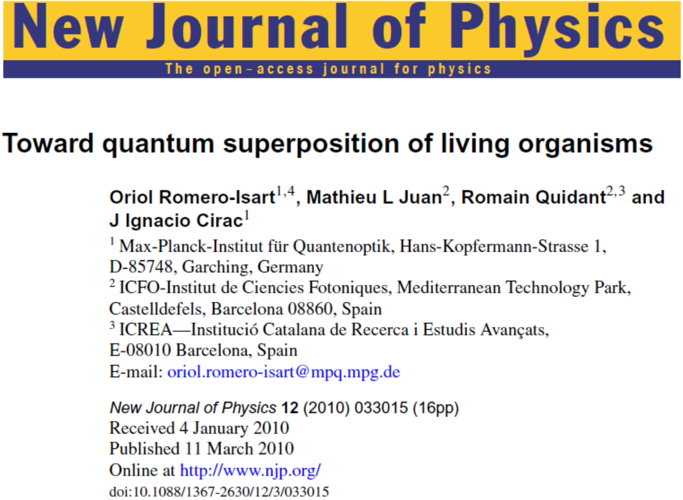
Las predicciones de la Mecánica Cuántica han sido comprobadas en numerosos ejemplos y en muy diversos regimenes. Sin embargo, su formulación, algunos de sus principios y la interpretación de dichos resultados ha sido, son, y serán objeto de debate, desde el comienzo mismo de la teoría. En algunos casos, el debate ha sido generado y dominado por el exceso de confianza depositado en ciertos gedankenexperiment (o "experimentos pensados"). En otros casos, la necesidad de formular reglas simples operacionales que especifiquen que predicciones se pueden comparar con resultados experimentales se confunde con un elemento "necesario" de la teoría. En este contexto "necesario" equivale a insatisfacorio y defectuoso. A esta altura, los pecados de la Mecánica Cuántica contra el ideal de belleza, elegancia y concisión que se demandan como elementos indispensables de una teoria fisica son parte del acervo cultural

Experimento pensado I



Experimento pensado II

un buen título



New Journal of Physics
The open-access journal for physics

Toward quantum superposition of living organisms

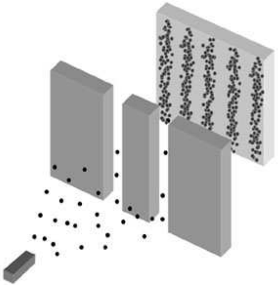
Oriol Romero-Isart[1,4], **Mathieu L Juan**[2], **Romain Quidant**[2,3] **and J Ignacio Cirac**[1]
[1] Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748, Garching, Germany
[2] ICFO-Institut de Ciencies Fotoniques, Mediterranean Technology Park, Castelldefels, Barcelona 08860, Spain
[3] ICREA—Institució Catalana de Recerca i Estudis Avançats, E-08010 Barcelona, Spain
E-mail: oriol.romero-isart@mpq.mpg.de

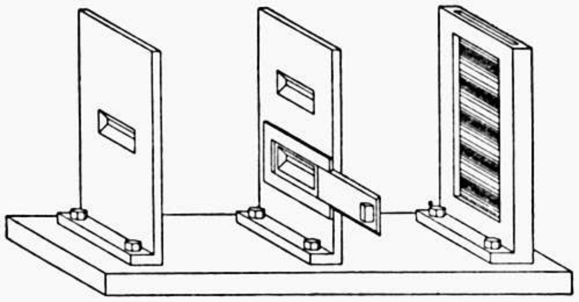
New Journal of Physics **12** (2010) 033015 (16pp)
Received 4 January 2010
Published 11 March 2010
Online at http://www.njp.org/
doi:10.1088/1367-2630/12/3/033015

spooky action at a distance

ring Spoiler Alert!!!

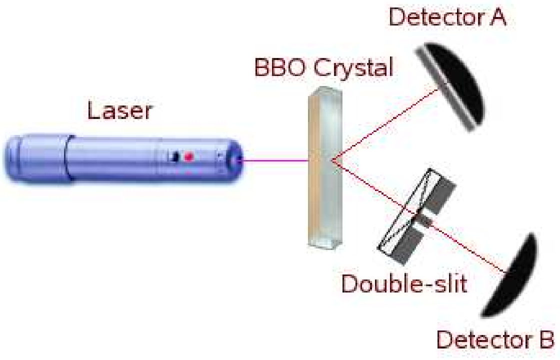
which-way experiments





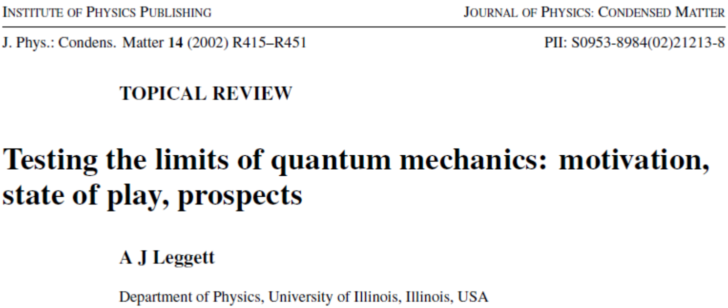
un “experimento” de acuerdo a Bohr!

the quantum eraser



el ”borrador cuántico“: 1. a laser fires photons into a Beta Barium Borate (BBO) crystal; the crystal entangles some of the photons; and then entangled photons travel to two different detectors: A and B.

La historia de acuerdo a A. Leggett



INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS: CONDENSED MATTER

J. Phys.: Condens. Matter **14** (2002) R415–R451 PII: S0953-8984(02)21213-8

TOPICAL REVIEW

Testing the limits of quantum mechanics: motivation, state of play, prospects

A J Leggett

Department of Physics, University of Illinois, Illinois, USA

La historia de acuerdo a A. Leggett I

- J. Phys.: Condens. Matter **14** (2002) R415 R451
- Quantum mechanics is very much more than just a “theory”; it is a completely new way of looking at the world, involving a change in paradigm perhaps more radical than any other in the history of human thought
- Despite this enormous range of applications, however, there is a sense in which we can say that the region of the whole parameter space over which the validity of QM has been directly tested is still rather modest. Take, for example, the question of length scale. The majority belief in the physics community would seem to be that the laws of physics as we currently understand them hold at all length scales down to the Planck scale ($\sim 10^{-35}$ m) and up to the size or “characteristic scale” of the Universe ($\sim 10^{+30}$ m) that is, over $\sim$ 65 orders of magnitude.
- In fact, if one were to ask over what length scales QM has been directly tested (in the sense of detection of characteristically QM effects such as interference) the answer would probably be: down to perhaps $\sim 10^{-18}$ m (in high-energy diffraction experiments) and up to a few metres or (recently) a few kilometres (in EPR-type experiments; see below) that is, over $<$ 30% of the total (logarithmic) range over which most people believe it to be valid. Similar remarks apply to scales of (e.g.) time and, even more, mass

La historia de acuerdo a A. Leggett I

- J. Phys.: Condens. Matter **14** (2002) R415 R451
- Quantum mechanics is very much more than just a “theory”; it is a completely new way of looking at the world, involving a change in paradigm perhaps more radical than any other in the history of human thought
- Despite this enormous range of applications, however, there is a sense in which we can say that the region of the whole parameter space over which the validity of QM has been directly tested is still rather modest. Take, for example, the question of length scale. The majority belief in the physics community would seem to be that the laws of physics as we currently understand them hold at all length scales down to the Planck scale ($\sim 10^{-35}$ m) and up to the size or “characteristic scale” of the Universe ($\sim 10^{+30}$ m) that is, over $\sim$ 65 orders of magnitude.
- In fact, if one were to ask over what length scales QM has been directly tested (in the sense of detection of characteristically QM effects such as interference) the answer would probably be: down to perhaps $\sim 10^{-18}$ m (in high-energy diffraction experiments) and up to a few metres or (recently) a few kilometres (in EPR-type experiments; see below) that is, over $<$ 30% of the total (logarithmic) range over which most people believe it to be valid. Similar remarks apply to scales of (e.g.) time and, even more, mass

La historia de acuerdo a A. Leggett I

- J. Phys.: Condens. Matter **14** (2002) R415 R451
- Quantum mechanics is very much more than just a "theory"; it is a completely new way of looking at the world, involving a change in paradigm perhaps more radical than any other in the history of human thought
- Despite this enormous range of applications, however, there is a sense in which we can say that the region of the whole parameter space over which the validity of QM has been directly tested is still rather modest. Take, for example, the question of length scale. The majority belief in the physics community would seem to be that the laws of physics as we currently understand them hold at all length scales down to the Planck scale ($\sim 10^{-35}$ m) and up to the size or "characteristic scale" of the Universe ($\sim 10^{+30}$ m) that is, over $\sim$ 65 orders of magnitude.
- In fact, if one were to ask over what length scales QM has been directly tested (in the sense of detection of characteristically QM effects such as interference) the answer would probably be: down to perhaps $\sim 10^{-18}$ m (in high-energy diffraction experiments) and up to a few metres or (recently) a few kilometres (in EPR-type experiments; see below) that is, over $<$ 30% of the total (logarithmic) range over which most people believe it to be valid. Similar remarks apply to scales of (e.g.) time and, even more, mass

La historia de acuerdo a A. Leggett I

- J. Phys.: Condens. Matter **14** (2002) R415 R451
- Quantum mechanics is very much more than just a “theory”; it is a completely new way of looking at the world, involving a change in paradigm perhaps more radical than any other in the history of human thought
- Despite this enormous range of applications, however, there is a sense in which we can say that the region of the whole parameter space over which the validity of QM has been directly tested is still rather modest. Take, for example, the question of length scale. The majority belief in the physics community would seem to be that the laws of physics as we currently understand them hold at all length scales down to the Planck scale ($\sim 10^{-35}$ m) and up to the size or “characteristic scale” of the Universe ($\sim 10^{+30}$ m) that is, over $\sim$ 65 orders of magnitude.
- In fact, if one were to ask over what length scales QM has been directly tested (in the sense of detection of characteristically QM effects such as interference) the answer would probably be: down to perhaps $\sim 10^{-18}$ m (in high-energy diffraction experiments) and up to a few metres or (recently) a few kilometres (in EPR-type experiments; see below) that is, over $<$ 30% of the total (logarithmic) range over which most people believe it to be valid. Similar remarks apply to scales of (e.g.) time and, even more, mass

La historia de acuerdo a A. Leggett 2

- three principal “directions” in which it is not unreasonable to look for a possible breakdown of QM.
- The first is the direction of very small length scales (which, to the extent that we stay within the relativistic quantum mechanical paradigm itself, is essentially equivalent to the direction of very short times and of high energies).
- The second direction in which itwould not, a priori, be unreasonable to conjecture a failure of QM is defined by the combination of (relatively) short times and (relatively) long distances, or more precisely, by the condition of space-like separation in the sense of special relativity.
- As is by now very widely known, in an epoch-making 1964 paper the late John Bell demonstrated that under such conditions the two-particle correlations predicted by QM are incompatible with a conjunction of very innocuous and commonsensical-looking postulates which nowadays are usually lumped together under the definition of an “objective local” theory; crudely speaking, this class of theories preserves the fundamental postulates of local causality in the sense of special relativity and a conventional concept of the “arrow” of time, and in addition makes the apparently “obvious” assumption that a spatially isolated system can be given a description in its own right. The intuitive plausibility (to many people) of the class of objective local theories is so high that once Bell had demonstrated that under suitable conditions (including the condition of space-like separation) no theory of this class can give experimental predictions which coincide with those made by QM, a number of people, including some very distinguished thinkers, committed themselves publicly to the opinion that it would be QM rather than the objective local postulates which would fail under these anomalous conditions
- Unfortenately for these sceptics, over the last 30 years a series of experiments of increasing ambitiousness1 have been made under just these conditions, and while there is still some argument (because of a couple of technical loopholes) about whether the outcome of these experiments excludes the class of objective local theories (a large majority of the physics community feels that it does), there is little argument that it is entirely consistent with the validity of the QM predictions.

La historia de acuerdo a A. Leggett 2

- three principal “directions” in which it is not unreasonable to look for a possible breakdown of QM.
- The first is the direction of very small length scales (which, to the extent that we stay within the relativistic quantum mechanical paradigm itself, is essentially equivalent to the direction of very short times and of high energies).
- The second direction in which itwould not, a priori, be unreasonable to conjecture a failure of QM is defined by the combination of (relatively) short times and (relatively) long distances, or more precisely, by the condition of space-like separation in the sense of special relativity.
- As is by now very widely known, in an epoch-making 1964 paper the late John Bell demonstrated that under such conditions the two-particle correlations predicted by QM are incompatible with a conjunction of very innocuous and commonsensical-looking postulates which nowadays are usually lumped together under the definition of an “objective local” theory; crudely speaking, this class of theories preserves the fundamental postulates of local causality in the sense of special relativity and a conventional concept of the “arrow” of time, and in addition makes the apparently “obvious” assumption that a spatially isolated system can be given a description in its own right. The intuitive plausibility (to many people) of the class of objective local theories is so high that once Bell had demonstrated that under suitable conditions (including the condition of space-like separation) no theory of this class can give experimental predictions which coincide with those made by QM, a number of people, including some very distinguished thinkers, committed themselves publicly to the opinion that it would be QM rather than the objective local postulates which would fail under these anomalous conditions
- Unfortenately for these sceptics, over the last 30 years a series of experiments of increasing ambitiousness1 have been made under just these conditions, and while there is still some argument (because of a couple of technical loopholes) about whether the outcome of these experiments excludes the class of objective local theories (a large majority of the physics community feels that it does), there is little argument that it is entirely consistent with the validity of the QM predictions.

La historia de acuerdo a A. Leggett 2

- three principal “directions” in which it is not unreasonable to look for a possible breakdown of QM.
- The first is the direction of very small length scales (which, to the extent that we stay within the relativistic quantum mechanical paradigm itself, is essentially equivalent to the direction of very short times and of high energies).
- The second direction in which itwould not, a priori, be unreasonable to conjecture a failure of QM is defined by the combination of (relatively) short times and (relatively) long distances, or more precisely, by the condition of space-like separation in the sense of special relativity.
- As is by now very widely known, in an epoch-making 1964 paper the late John Bell demonstrated that under such conditions the two-particle correlations predicted by QM are incompatible with a conjunction of very innocuous and commonsensical-looking postulates which nowadays are usually lumped together under the definition of an “objective local” theory; crudely speaking, this class of theories preserves the fundamental postulates of local causality in the sense of special relativity and a conventional concept of the “arrow” of time, and in addition makes the apparently “obvious” assumption that a spatially isolated system can be given a description in its own right. The intuitive plausibility (to many people) of the class of objective local theories is so high that once Bell had demonstrated that under suitable conditions (including the condition of space-like separation) no theory of this class can give experimental predictions which coincide with those made by QM, a number of people, including some very distinguished thinkers, committed themselves publicly to the opinion that it would be QM rather than the objective local postulates which would fail under these anomalous conditions
- Unfortenately for these sceptics, over the last 30 years a series of experiments of increasing ambitiousness1 have been made under just these conditions, and while there is still some argument (because of a couple of technical loopholes) about whether the outcome of these experiments excludes the class of objective local theories (a large majority of the physics community feels that it does), there is little argument that it is entirely consistent with the validity of the QM predictions.

La historia de acuerdo a A. Leggett 2

- three principal “directions” in which it is not unreasonable to look for a possible breakdown of QM.
- The first is the direction of very small length scales (which, to the extent that we stay within the relativistic quantum mechanical paradigm itself, is essentially equivalent to the direction of very short times and of high energies).
- The second direction in which itwould not, a priori, be unreasonable to conjecture a failure of QM is defined by the combination of (relatively) short times and (relatively) long distances, or more precisely, by the condition of space-like separation in the sense of special relativity.
- As is by now very widely known, in an epoch-making 1964 paper the late John Bell demonstrated that under such conditions the two-particle correlations predicted by QM are incompatible with a conjunction of very innocuous and commonsensical-looking postulates which nowadays are usually lumped together under the definition of an “objective local” theory; crudely speaking, this class of theories preserves the fundamental postulates of local causality in the sense of special relativity and a conventional concept of the “arrow” of time, and in addition makes the apparently “obvious” assumption that a spatially isolated system can be given a description in its own right. The intuitive plausibility (to many people) of the class of objective local theories is so high that once Bell had demonstrated that under suitable conditions (including the condition of space-like separation) no theory of this class can give experimental predictions which coincide with those made by QM, a number of people, including some very distinguished thinkers, committed themselves publicly to the opinion that it would be QM rather than the objective local postulates which would fail under these anomalous conditions
- Unfortenately for these sceptics, over the last 30 years a series of experiments of increasing ambitiousness1 have been made under just these conditions, and while there is still some argument (because of a couple of technical loopholes) about whether the outcome of these experiments excludes the class of objective local theories (a large majority of the physics community feels that it does), there is little argument that it is entirely consistent with the validity of the QM predictions.

La historia de acuerdo a A. Leggett 2

- three principal “directions” in which it is not unreasonable to look for a possible breakdown of QM.
- The first is the direction of very small length scales (which, to the extent that we stay within the relativistic quantum mechanical paradigm itself, is essentially equivalent to the direction of very short times and of high energies).
- The second direction in which itwould not, a priori, be unreasonable to conjecture a failure of QM is defined by the combination of (relatively) short times and (relatively) long distances, or more precisely, by the condition of space-like separation in the sense of special relativity.
- As is by now very widely known, in an epoch-making 1964 paper the late John Bell demonstrated that under such conditions the two-particle correlations predicted by QM are incompatible with a conjunction of very innocuous and commonsensical-looking postulates which nowadays are usually lumped together under the definition of an “objective local” theory; crudely speaking, this class of theories preserves the fundamental postulates of local causality in the sense of special relativity and a conventional concept of the “arrow” of time, and in addition makes the apparently “obvious” assumption that a spatially isolated system can be given a description in its own right. The intuitive plausibility (to many people) of the class of objective local theories is so high that once Bell had demonstrated that under suitable conditions (including the condition of space-like separation) no theory of this class can give experimental predictions which coincide with those made by QM, a number of people, including some very distinguished thinkers, committed themselves publicly to the opinion that it would be QM rather than the objective local postulates which would fail under these anomalous conditions
- Unfortenately for these sceptics, over the last 30 years a series of experiments of increasing ambitiousness1 have been made under just these conditions, and while there is still some argument (because of a couple of technical loopholes) about whether the outcome of these experiments excludes the class of objective local theories (a large majority of the physics community feels that it does), there is little argument that it is entirely consistent with the validity of the QM predictions.

La historia de acuerdo a A. Leggett 3

- The third “axis” along which it is not unreasonable to seek evidence of a breakdown of the quantum mechanical scheme of the physical world is that which connects the world of atoms and electrons, for which it was originally developed, with the “everyday” world of our immediate experience
- acerca del problema de medición:“of the three major classes of “resolution” of the quantum measurement paradox, the “orthodox” one involves a major logical fallacy and the “manyworlds” interpretation is simply a meaningless collage of words. The “statistical” interpretation, if taken to its logical conclusion, is internally consistent but conflicts rather violently with the “realistic” intuitions which most practising physicists probably find not only philosophically congenial, but almost essential, psychologically, in their everyday work. Thus, one is led to consider the possibility that the fundamental premise of the argument is wrong: that is, that the linear formalism of QM does not apply in unmodified form to macroscopic systems in the same way as it does to their microscopic constituents.”

La historia de acuerdo a A. Leggett 3

- The third “axis” along which it is not unreasonable to seek evidence of a breakdown of the quantum mechanical scheme of the physical world is that which connects the world of atoms and electrons, for which it was originally developed, with the “everyday” world of our immediate experience
- acerca del problema de medición:“of the three major classes of “resolution” of the quantum measurement paradox, the “orthodox” one involves a major logical fallacy and the “manyworlds” interpretation is simply a meaningless collage of words. The “statistical” interpretation, if taken to its logical conclusion, is internally consistent but conflicts rather violently with the “realistic” intuitions which most practising physicists probably find not only philosophically congenial, but almost essential, psychologically, in their everyday work. Thus, one is led to consider the possibility that the fundamental premise of the argument is wrong: that is, that the linear formalism of QM does not apply in unmodified form to macroscopic systems in the same way as it does to their microscopic constituents.”

Legget no esta solo 1

- Supplement of the Progress of Theoretical Physics, No. 69, 1980

  Macroscopic Quantum Systems and the Quantum Theory of Measurement

  This paper discusses the question: How far do experiments on the so-called "macroscopic quantum systems" such as superfluids and superconductors test the hypothesis that the linear Schrodinger equation may be extrapolated to arbitrarily complex systems? It is shown that the familiar "macroscopic quantum phenomena" such as flux quantization and the Josephson effect are irrelevant in this context, because they correspond to states having a very small value of a certain critical property (christened" disconnectivity") while the states important for a discussion of the quantum theory of measurement have a very high value of this property. Various possibilities for verifying experimentally the existence of such states are discussed, with the conclusion that the most promising is probably the observation of quantum tunnelling between states with macroscopically different properties. It is shown that because of their very high "quantum purity" and consequent very low dissipation at low temperatures, superconducting systems (in particular SQUID rings) offer good prospects for such an observation.
- by A. Legget

Legget no esta solo 1

- Supplement of the Progress of Theoretical Physics, No. 69, 1980

  Macroscopic Quantum Systems and the Quantum Theory of Measurement

  This paper discusses the question: How far do experiments on the so-called "macroscopic quantum systems" such as superfluids and superconductors test the hypothesis that the linear Schrodinger equation may be extrapolated to arbitrarily complex systems? It is shown that the familiar "macroscopic quantum phenomena" such as flux quantization and the Josephson effect are irrelevant in this context, because they correspond to states having a very small value of a certain critical property (christened" disconnectivity") while the states important for a discussion of the quantum theory of measurement have a very high value of this property. Various possibilities for verifying experimentally the existence of such states are discussed, with the conclusion that the most promising is probably the observation of quantum tunnelling between states with macroscopically different properties. It is shown that because of their very high "quantum purity" and consequent very low dissipation at low temperatures, superconducting systems (in particular SQUID rings) offer good prospects for such an observation.

- by A. Legget

Legget no esta solo 2

- Probing Quantum Mechanics towards the Everyday World
  How Far Have We Come?
- Progress of Theoretical Physics Supplement No. 170, 2007
- A. J. Leggett
- I present the motivation for experiments which attempt to generate, and verify the existence of, quantum superpositions of two or more states which are by some reasonable criterion "macroscopicall" distinct, and show that various a priori objections to this program made in the literature are flawed. I review the extent to which such experiments currently exist in the areas of free-space molecular diffraction, magnetic biomolecules, quantum optics and Josephson devices, and sketch possible future lines of development of the program.

Legget no esta solo 2

- Probing Quantum Mechanics towards the Everyday World
  How Far Have We Come?
- Progress of Theoretical Physics Supplement No. 170, 2007
- A. J. Leggett
- I present the motivation for experiments which attempt to generate, and verify the existence of, quantum superpositions of two or more states which are by some reasonable criterion “macroscopicall” distinct, and show that various a priori objections to this program made in the literature are flawed. I review the extent to which such experiments currently exist in the areas of free-space molecular diffraction, magnetic biomolecules, quantum optics and Josephson devices, and sketch possible future lines of development of the program.

Legget no esta solo 2

- Probing Quantum Mechanics towards the Everyday World
  How Far Have We Come?
- Progress of Theoretical Physics Supplement No. 170, 2007
- A. J. Leggett
- I present the motivation for experiments which attempt to generate, and verify the existence of, quantum superpositions of two or more states which are by some reasonable criterion “macroscopicall” distinct, and show that various a priori objections to this program made in the literature are flawed. I review the extent to which such experiments currently exist in the areas of free-space molecular diffraction, magnetic biomolecules, quantum optics and Josephson devices, and sketch possible future lines of development of the program.

Legget no esta solo 2

- Probing Quantum Mechanics towards the Everyday World
  How Far Have We Come?
- Progress of Theoretical Physics Supplement No. 170, 2007
- A. J. Leggett
- I present the motivation for experiments which attempt to generate, and verify the existence of, quantum superpositions of two or more states which are by some reasonable criterion "macroscopicall" distinct, and show that various a priori objections to this program made in the literature are flawed. I review the extent to which such experiments currently exist in the areas of free-space molecular diffraction, magnetic biomolecules, quantum optics and Josephson devices, and sketch possible future lines of development of the program.

Legget no esta solo 3

- Experiment and the foundations of quantum physics
- Anton Zeilinger
- Instead of having to rely on gedanken (thought) experiments, it is possible to base this discussion of the foundations of quantum physics on actually performed experiments because of the enormous experimental progress in recent years. For reasons of space, the author discusses mainly experiments related to the Einstein-Podolsky-Rosen paradox and Bell's theorem, that is, to quantum entanglement. Not only have such fundamental experiments realized many historic proposals, they also helped to sharpen our quantum intuition. This recently led to the development of a new field, quantum information, where quantum teleportation and quantum computation are some of the most fascinating topics. Finally the author ventures into a discussion of future prospects in experiment and theory.
- Reviews of Modern Physics, Vol. 71, No. 2, Centenary 1999

Legget no esta solo 3

- Experiment and the foundations of quantum physics
- Anton Zeilinger
- Instead of having to rely on gedanken (thought) experiments, it is possible to base this discussion of the foundations of quantum physics on actually performed experiments because of the enormous experimental progress in recent years. For reasons of space, the author discusses mainly experiments related to the Einstein-Podolsky-Rosen paradox and Bell's theorem, that is, to quantum entanglement. Not only have such fundamental experiments realized many historic proposals, they also helped to sharpen our quantum intuition. This recently led to the development of a new field, quantum information, where quantum teleportation and quantum computation are some of the most fascinating topics. Finally the author ventures into a discussion of future prospects in experiment and theory.
- Reviews of Modern Physics, Vol. 71, No. 2, Centenary 1999

Legget no esta solo 3

- Experiment and the foundations of quantum physics
- Anton Zeilinger
- Instead of having to rely on gedanken (thought) experiments, it is possible to base this discussion of the foundations of quantum physics on actually performed experiments because of the enormous experimental progress in recent years. For reasons of space, the author discusses mainly experiments related to the Einstein-Podolsky-Rosen paradox and Bell's theorem, that is, to quantum entanglement. Not only have such fundamental experiments realized many historic proposals, they also helped to sharpen our quantum intuition. This recently led to the development of a new field, quantum information, where quantum teleportation and quantum computation are some of the most fascinating topics. Finally the author ventures into a discussion of future prospects in experiment and theory.
- Reviews of Modern Physics, Vol. 71, No. 2, Centenary 1999

Legget no esta solo 3

- Experiment and the foundations of quantum physics
- Anton Zeilinger
- Instead of having to rely on gedanken (thought) experiments, it is possible to base this discussion of the foundations of quantum physics on actually performed experiments because of the enormous experimental progress in recent years. For reasons of space, the author discusses mainly experiments related to the Einstein-Podolsky-Rosen paradox and Bell's theorem, that is, to quantum entanglement. Not only have such fundamental experiments realized many historic proposals, they also helped to sharpen our quantum intuition. This recently led to the development of a new field, quantum information, where quantum teleportation and quantum computation are some of the most fascinating topics. Finally the author ventures into a discussion of future prospects in experiment and theory.
- Reviews of Modern Physics, Vol. 71, No. 2, Centenary 1999

Legget no esta solo 4

- en palabras del troesma
- So, where is the problem? The problem arises when one realizes that quantum physics implies a number of very counterintuitive concepts and notions. This has led, for example, R. P. Feynman to remark, “I think I can safely say that nobody today understands quantum physics,” or Roger Penrose (1986) to comment that the theory “makes absolutely no sense.”
- From the beginning, gedanken (thought) experiments were used to discuss fundamental issues in quantum physics. At that time, Heisenberg invented his gedanken gamma-ray microscope to demonstrate the uncertainty principle while Niels Bohr and Albert Einstein in their famous dialogue on epistemological problems in what was then called atomic physics made extensive use of gedanken experiments to make their points.
- Now, at the end of the 20th century, the situation has changed dramatically. Real experiments on the foundations of quantum physics abound. This has not only given dramatic support to the early views, it has also helped to sharpen our intuition with respect to quantum phenomena. Most recently, experimentation is already applying some of the fundamental phenomena in completely novel ways. For example, quantum cryptography is a direct application of quantum uncertainty and both quantum teleportation and quantum computation are direct applications of quantum entanglement, the concept underlying quantum nonlocality (Schrödinger, 1935).

Legget no esta solo 4

- en palabras del troesma
- So, where is the problem? The problem arises when one realizes that quantum physics implies a number of very counterintuitive concepts and notions. This has led, for example, R. P. Feynman to remark, “I think I can safely say that nobody today understands quantum physics,” or Roger Penrose (1986) to comment that the theory “makes absolutely no sense.”
- From the beginning, gedanken (thought) experiments were used to discuss fundamental issues in quantum physics. At that time, Heisenberg invented his gedanken gamma-ray microscope to demonstrate the uncertainty principle while Niels Bohr and Albert Einstein in their famous dialogue on epistemological problems in what was then called atomic physics made extensive use of gedanken experiments to make their points.
- Now, at the end of the 20th century, the situation has changed dramatically. Real experiments on the foundations of quantum physics abound. This has not only given dramatic support to the early views, it has also helped to sharpen our intuition with respect to quantum phenomena. Most recently, experimentation is already applying some of the fundamental phenomena in completely novel ways. For example, quantum cryptography is a direct application of quantum uncertainty and both quantum teleportation and quantum computation are direct applications of quantum entanglement, the concept underlying quantum nonlocality (Schrödinger, 1935).

Legget no esta solo 4

- en palabras del troesma
- So, where is the problem? The problem arises when one realizes that quantum physics implies a number of very counterintuitive concepts and notions. This has led, for example, R. P. Feynman to remark, “I think I can safely say that nobody today understands quantum physics,” or Roger Penrose (1986) to comment that the theory “makes absolutely no sense.”
- From the beginning, gedanken (thought) experiments were used to discuss fundamental issues in quantum physics. At that time, Heisenberg invented his gedanken gamma-ray microscope to demonstrate the uncertainty principle while Niels Bohr and Albert Einstein in their famous dialogue on epistemological problems in what was then called atomic physics made extensive use of gedanken experiments to make their points.
- Now, at the end of the 20th century, the situation has changed dramatically. Real experiments on the foundations of quantum physics abound. This has not only given dramatic support to the early views, it has also helped to sharpen our intuition with respect to quantum phenomena. Most recently, experimentation is already applying some of the fundamental phenomena in completely novel ways. For example, quantum cryptography is a direct application of quantum uncertainty and both quantum teleportation and quantum computation are direct applications of quantum entanglement, the concept underlying quantum nonlocality (Schrödinger, 1935).

Legget no esta solo 4

- en palabras del troesma
- So, where is the problem? The problem arises when one realizes that quantum physics implies a number of very counterintuitive concepts and notions. This has led, for example, R. P. Feynman to remark, “I think I can safely say that nobody today understands quantum physics,” or Roger Penrose (1986) to comment that the theory “makes absolutely no sense.”
- From the beginning, gedanken (thought) experiments were used to discuss fundamental issues in quantum physics. At that time, Heisenberg invented his gedanken gamma-ray microscope to demonstrate the uncertainty principle while Niels Bohr and Albert Einstein in their famous dialogue on epistemological problems in what was then called atomic physics made extensive use of gedanken experiments to make their points.
- Now, at the end of the 20th century, the situation has changed dramatically. Real experiments on the foundations of quantum physics abound. This has not only given dramatic support to the early views, it has also helped to sharpen our intuition with respect to quantum phenomena. Most recently, experimentation is already applying some of the fundamental phenomena in completely novel ways. For example, quantum cryptography is a direct application of quantum uncertainty and both quantum teleportation and quantum computation are direct applications of quantum entanglement, the concept underlying quantum nonlocality (Schrödinger, 1935).

This is a call to all my ....predecessors?

- acerca de los riesgos de tratar de hacer un “estado del arte” de la MC en estos años
- en su primer review Legget presenta su “distinguibilidad” ....solo unos años después quedaría claro de que estaba hablando de ... entrelazamiento
- en su segundo review Legget dice que no se va preocupar por el “límite inferior” ya que este se encuentra “por muchos años fuera del alcance de ser testeado experimentalmente”

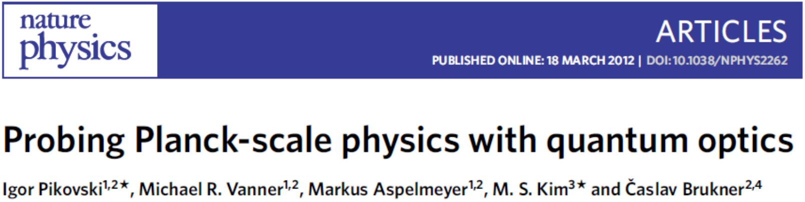
This is a call to all my ....predecessors?

- acerca de los riesgos de tratar de hacer un “estado del arte” de la MC en estos años
- en su primer review Legget presenta su “distinguibilidad” ....solo unos años después quedaría claro de que estaba hablando de ... entrelazamiento
- en su segundo review Legget dice que no se va preocupar por el “límite inferior” ya que este se encuentra “por muchos años fuera del alcance de ser testeado experimentalmente”

This is a call to all my ....predecessors?

- acerca de los riesgos de tratar de hacer un “estado del arte” de la MC en estos años
- en su primer review Legget presenta su “distinguibilidad” ....solo unos años después quedaría claro de que estaba hablando de ... entrelazamiento
- en su segundo review Legget dice que no se va preocupar por el “límite inferior” ya que este se encuentra “por muchos años fuera del alcance de ser testeado experimentalmente”

to Planck scale or bust



nature physics

ARTICLES

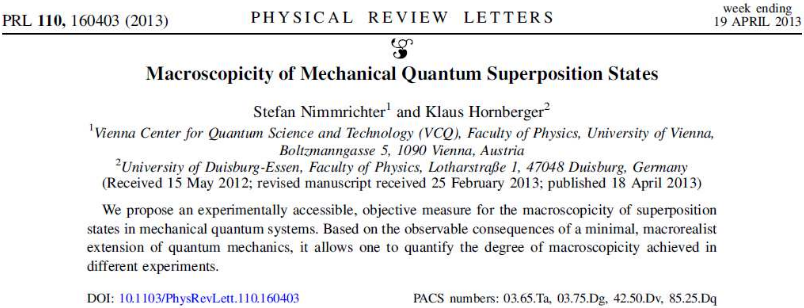
PUBLISHED ONLINE: 18 MARCH 2012 | DOI:10.1038/NPHYS2262

Probing Planck-scale physics with quantum optics

Igor Pikovski[1,2]*, Michael R. Vanner[1,2], Markus Aspelmeyer[1,2], M. S. Kim[3]* and Časlav Brukner[2,4]

- One of the main challenges in physics today is to merge quantum theory and the theory of general relativity into a unified framework. Researchers are developing various approaches towards such a theory of quantum gravity, but a major hindrance is the lack of experimental evidence of quantum gravitational effects. Yet, the quantization of spacetime itself can have experimental implications: the existence of a minimal length scale is widely expected to result in a modification of the Heisenberg uncertainty relation. Here we introduce a scheme to experimentally test this conjecture by probing directly the canonical commutation relation of the centre-of-mass mode of a mechanical oscillator with a mass close to the Planck mass. Our protocol uses quantum optical control and readout of the mechanical systemto probe possible deviations from the quantum commutation relation even at the Planck scale.We show that the scheme is within reach of current technology. It thus opens a feasible route for table-top experiments to explore possible quantum gravitational phenomena.

Microscópico-Macroscópico 1



PRL **110**, 160403 (2013) PHYSICAL REVIEW LETTERS week ending 19 APRIL 2013

Macroscopicity of Mechanical Quantum Superposition States

Stefan Nimmrichter[1] and Klaus Hornberger[2]
[1]*Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria*
[2]*University of Duisburg-Essen, Faculty of Physics, Lotharstraße 1, 47048 Duisburg, Germany*

(Received 15 May 2012; revised manuscript received 25 February 2013; published 18 April 2013)

We propose an experimentally accessible, objective measure for the macroscopicity of superposition states in mechanical quantum systems. Based on the observable consequences of a minimal, macrorealist extension of quantum mechanics, it allows one to quantify the degree of macroscopicity achieved in different experiments.

DOI: 10.1103/PhysRevLett.110.160403 PACS numbers: 03.65.Ta, 03.75.Dg, 42.50.Dv, 85.25.Dq

Microscópico-Macroscópico 2

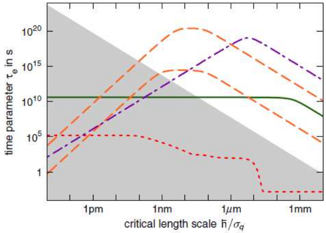


FIG. 1 (color online). Lower bounds on the time parameter τ_e, as set by various experiments. The calculations are done for the relevant range of critical length scales $\hbar/\sigma_q$, and at $\sigma_s = 20$ pm. The solid line corresponds to the atom interferometer of Ref. [29]; it rules out all time parameters τ_e below the curve. Future experiments may exclude a larger set, e.g., by interference of 10^5–10^7 amu gold clusters [30] (dashed lines) or of micromirror motion [31] (dash-dotted line). The dotted line corresponds to demonstrated persistent current superpostions in a SQUID loop [1]. The shaded region represents the excluded τ_e by a conceivable classical measurement of less than 1 μK/s temperature increase in a Rb gas.

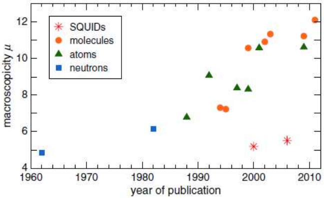


FIG. 2 (color online). Timeline of macroscopicities reached in quantum superposition experiments [22]. The squares, the triangles, and the dots represent interference experiments with neutrons [37,38], atoms [29,39–42] or atom Bose-Einstein condensates [3], and molecules [4,43–48], respectively. One notes that Bose-Einstein condensates do not substantially exceed the macroscopicities achieved with atom interferometers. This is due to the single-particle nature of the condensate wave function. The many-particle state is more involved in the case of superposition experiments with persistent supercurrent states in a large SQUID loop [1,2], as represented by the stars. However, despite the large number of Cooper pairs contributing to the current superpositions in SQUIDs, such experiments lag behind in macroscopicity due to the small coherence times observed.

Microscópico-Macroscópico 3

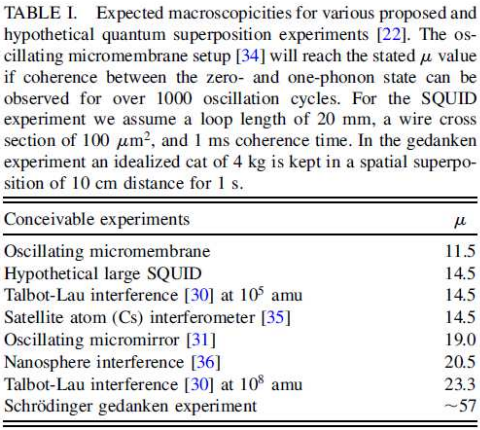
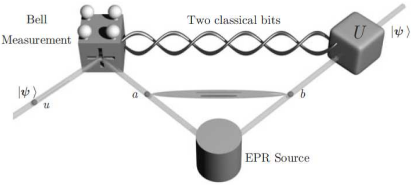
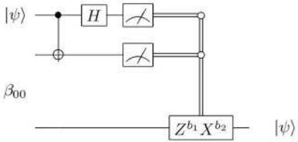


TABLE I. Expected macroscopicities for various proposed and hypothetical quantum superposition experiments [22]. The oscillating micromembrane setup [34] will reach the stated μ value if coherence between the zero- and one-phonon state can be observed for over 1000 oscillation cycles. For the SQUID experiment we assume a loop length of 20 mm, a wire cross section of 100 μm^2, and 1 ms coherence time. In the gedanken experiment an idealized cat of 4 kg is kept in a spatial superposition of 10 cm distance for 1 s.

Conceivable experiments	μ
Oscillating micromembrane	11.5
Hypothetical large SQUID	14.5
Talbot-Lau interference [30] at 10^5 amu	14.5
Satellite atom (Cs) interferometer [35]	14.5
Oscillating micromirror [31]	19.0
Nanosphere interference [36]	20.5
Talbot-Lau interference [30] at 10^8 amu	23.3
Schrödinger gedanken experiment	$\sim$57

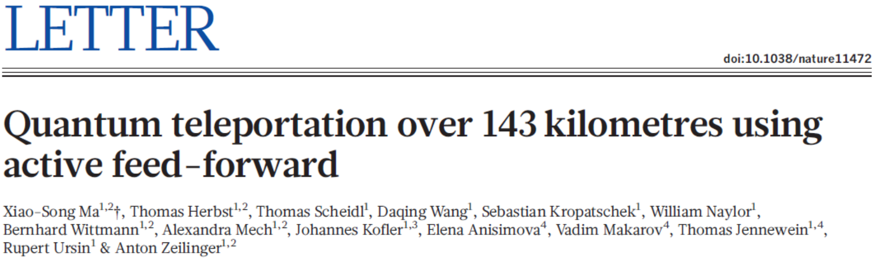
Teleportación I





The seminal paper first expounding the idea was published by C. H. Bennett, G. Brassard, C. Crépeau, R. Jozsa, A. Peres and W. K. Wootters in 1993. Work in 1998 verified the initial predictions [D. Boschi; S. Branca; F. De Martini; L. Hardy; S. Popescu (1998). "Experimental Realization of Teleporting an Unknown Pure Quantum State via Dual Classical and Einstein-Podolsky-Rosen Channels". Physical Review Letters 80 (6): 1121] and the distance of teleportation was increased in August 2004 to 600 meters, using optical fiber.

Teleportación II



LETTER

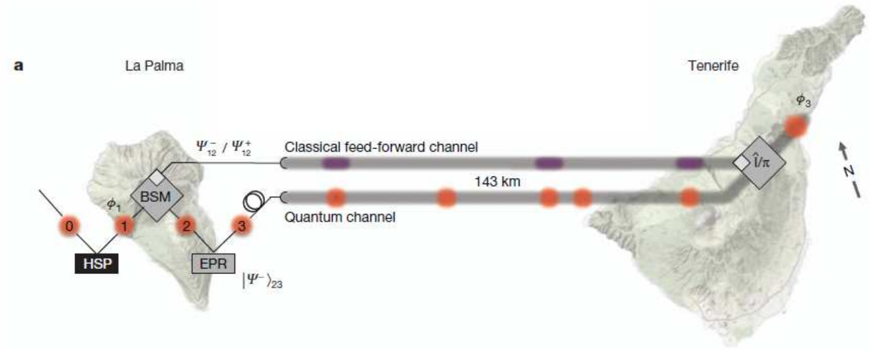
doi:10.1038/nature11472

Quantum teleportation over 143 kilometres using active feed-forward

Xiao-Song Ma[1,2]†, Thomas Herbst[1,2], Thomas Scheidl[1], Daqing Wang[1], Sebastian Kropatschek[1], William Naylor[1], Bernhard Wittmann[1,2], Alexandra Mech[1,2], Johannes Kofler[1,3], Elena Anisimova[4], Vadim Makarov[4], Thomas Jennewein[1,4], Rupert Ursin[1] & Anton Zeilinger[1,2]

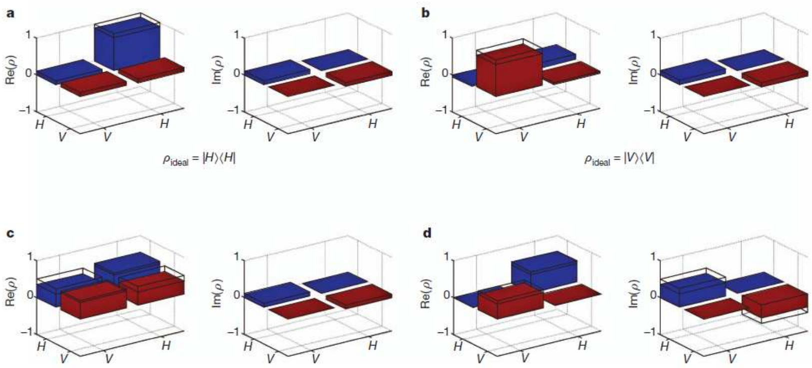
The longest distance yet claimed to be achieved for quantum teleportation is 143 km (89 mi), performed in May 2012, between the two Canary Islands of La Palma and Tenerife off the Atlantic coast of north Africa

Teleportación III



The longest distance yet claimed to be achieved for quantum teleportation is 143 km (89 mi), performed in May 2012, between the two Canary Islands of La Palma and Tenerife off the Atlantic coast of north Africa

Teleportación IV



$\rho_{\text{ideal}} = |H\rangle\langle H|$

$\rho_{\text{ideal}} = |V\rangle\langle V|$

$\rho_{\text{ideal}} = \frac{1}{2}(|H\rangle\langle H| + |H\rangle\langle V| + |V\rangle\langle H| + |V\rangle\langle V|)$

$\rho_{\text{ideal}} = \frac{1}{2}(|H\rangle\langle H| + i|H\rangle\langle V| - i|V\rangle\langle H| + |V\rangle\langle V|)$

Figure 2 | State tomography results of the four quantum states without feed-forward over the 143-km free-space channel with the BSM outcome of $|\Psi^-\rangle_{12}$. The bar graphs show the reconstructed density matrices ρ for the four states teleported from Alice (La Palma) to Bob (Tenerife) over the 143-km free-space channel. The wire grid indicates the expected values for the ideal cases. The data shown comprise a total of 605 fourfold coincidence counts in about 6.5 h. The uncertainties in state fidelities extracted from these density matrices are calculated using a Monte Carlo routine assuming Poissonian errors.

Desigualdades de Bell: historia?

- EPR, Phys. Rev. **47**, 777 (1935)
- At age 67 (in 1946 or early 1947), Einstein wrote a short scientific autobiography [3] in which he set out his views on the foundations of physics in depth. There he referred to “the most successful physical theory of our period, viz. the statistical quantum theory” (A. Einstein, “Autobiographical Notes”, in P. A. Schilpp (ed.), Albert Einstein: Philosopher-Scientist (Library of the Living Philosophers, Evanston, 1949).
- John Bell, Physics **1**, 195 (1964)

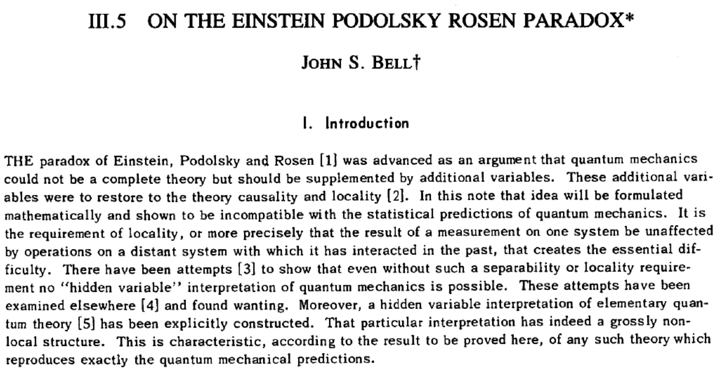
Desigualdades de Bell: historia?

- EPR, Phys. Rev. **47**, 777 (1935)
- At age 67 (in 1946 or early 1947), Einstein wrote a short scientific autobiography [3] in which he set out his views on the foundations of physics in depth. There he referred to “the most successful physical theory of our period, viz. the statistical quantum theory” (A. Einstein, “Autobiographical Notes”, in P. A. Schilpp (ed.), Albert Einstein: Philosopher-Scientist (Library of the Living Philosophers, Evanston, 1949).
- John Bell, Physics **1**, 195 (1964)

Desigualdades de Bell: historia?

- EPR, Phys. Rev. **47**, 777 (1935)
- At age 67 (in 1946 or early 1947), Einstein wrote a short scientific autobiography [3] in which he set out his views on the foundations of physics in depth. There he referred to “the most successful physical theory of our period, viz. the statistical quantum theory” (A. Einstein, “Autobiographical Notes”, in P. A. Schilpp (ed.), Albert Einstein: Philosopher-Scientist (Library of the Living Philosophers, Evanston, 1949).
- John Bell, Physics **1**, 195 (1964)

Bell by himself



III.5 ON THE EINSTEIN PODOLSKY ROSEN PARADOX*

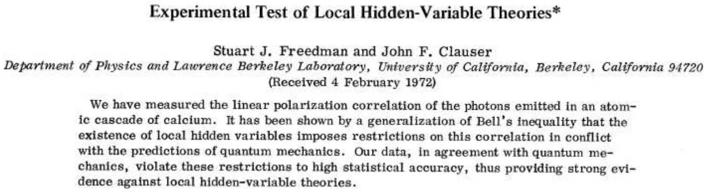
JOHN S. BELL†

I. Introduction

THE paradox of Einstein, Podolsky and Rosen [1] was advanced as an argument that quantum mechanics could not be a complete theory but should be supplemented by additional variables. These additional variables were to restore to the theory causality and locality [2]. In this note that idea will be formulated mathematically and shown to be incompatible with the statistical predictions of quantum mechanics. It is the requirement of locality, or more precisely that the result of a measurement on one system be unaffected by operations on a distant system with which it has interacted in the past, that creates the essential difficulty. There have been attempts [3] to show that even without such a separability or locality requirement no "hidden variable" interpretation of quantum mechanics is possible. These attempts have been examined elsewhere [4] and found wanting. Moreover, a hidden variable interpretation of elementary quantum theory [5] has been explicitly constructed. That particular interpretation has indeed a grossly non-local structure. This is characteristic, according to the result to be proved here, of any such theory which reproduces exactly the quantum mechanical predictions.

[3] von Neumann
[4] Bell
[5]Bohm

Primer test



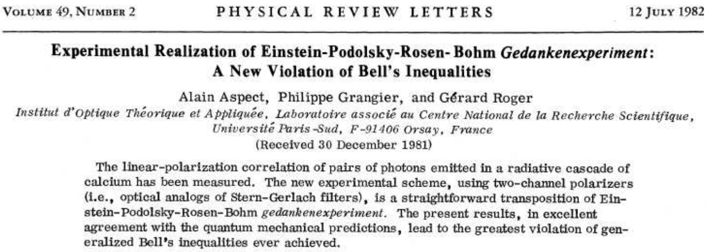
Experimental Test of Local Hidden-Variable Theories*

Stuart J. Freedman and John F. Clauser
Department of Physics and Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720
(Received 4 February 1972)

We have measured the linear polarization correlation of the photons emitted in an atomic cascade of calcium. It has been shown by a generalization of Bell's inequality that the existence of local hidden variables imposes restrictions on this correlation in conflict with the predictions of quantum mechanics. Our data, in agreement with quantum mechanics, violate these restrictions to high statistical accuracy, thus providing strong evidence against local hidden-variable theories.

one-channel experiment

a Bell ...a history begins



VOLUME 49, NUMBER 2 PHYSICAL REVIEW LETTERS 12 JULY 1982

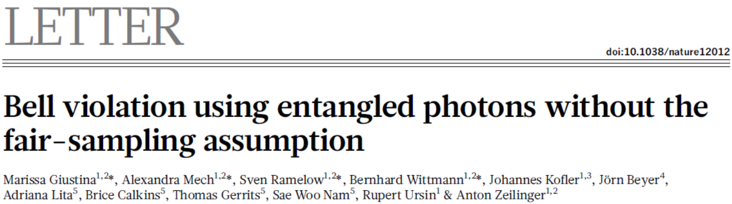
Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedankenexperiment*: A New Violation of Bell's Inequalities

Alain Aspect, Philippe Grangier, and Gérard Roger
Institut d'Optique Théorique et Appliquée, Laboratoire associé au Centre National de la Recherche Scientifique, Université Paris-Sud, F-91406 Orsay, France

(Received 30 December 1981)

The linear-polarization correlation of pairs of photons emitted in a radiative cascade of calcium has been measured. The new experimental scheme, using two-channel polarizers (i.e., optical analogs of Stern-Gerlach filters), is a straightforward transposition of Einstein-Podolsky-Rosen-Bohm *gedankenexperiment*. The present results, in excellent agreement with the quantum mechanical predictions, lead to the greatest violation of generalized Bell's inequalities ever achieved.

This is the end?



LETTER

doi:10.1038/nature12012

Bell violation using entangled photons without the fair-sampling assumption

Marissa Giustina[1,2]*, Alexandra Mech[1,2]*, Sven Ramelow[1,2]*, Bernhard Wittmann[1,2]*, Johannes Kofler[1,3], Jörn Beyer[4], Adriana Lita[5], Brice Calkins[5], Thomas Gerrits[5], Sae Woo Nam[5], Rupert Ursin[1] & Anton Zeilinger[1,2]

- The violation of a Bell inequality is an experimental observation that forces the abandonment of a local realistic viewpoint- namely, one in which physical properties are (probabilistically) defined before and independently of measurement, and in which no physical influence can propagate faster than the speed of light. All such experimental violations require additional assumptions depending on their specific construction, making them vulnerable to so-called loopholes. Here we use entangled photons to violate a Bell inequality while closing the fair-sampling loophole, that is, without assuming that the sample of measured photons accurately represents the entire ensemble3. To do this, we use the Eberhard form of Bell's inequality, which is not vulnerable to the fairsampling assumption and which allows a lower collection efficiency than other forms. Technical improvements of the photon source and high-efficiency transition-edge sensors were crucial for achieving a sufficiently high collection efficiency. Our experiment makes the photon the first physical system for which each of the main loopholes has been closed, albeit in different experiments. [Nature 497, 227, May 2013]

superpuestos pero no amontonados 1

nature physics

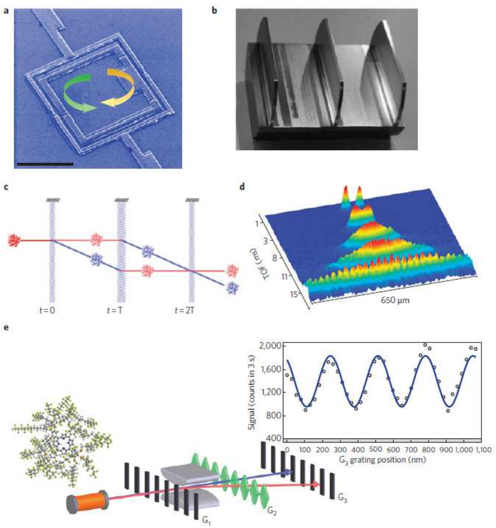
INSIGHT | REVIEW ARTICLES

Testing the limits of quantum mechanical superpositions

Markus Arndt[1*] and Klaus Hornberger[2†]

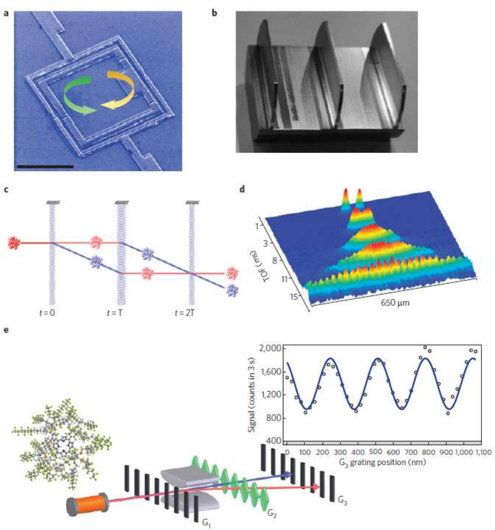
Quantum physics has intrigued scientists and philosophers alike, because it challenges our notions of reality and locality — concepts that we have grown to rely on in our macroscopic world. It is an intriguing open question whether the linearity of quantum mechanics extends into the macroscopic domain. Scientific progress over the past decades inspires hope that this debate may be settled by table-top experiments.

superpuestos pero no amontonados 1



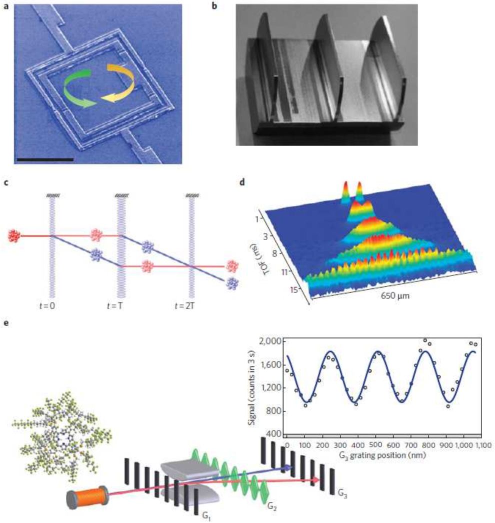
Superposition experiments. a, A flux qubit realizes a quantum superposition of left- and right-circulating supercurrents with billions of electrons contributing to the quantum state. b, Neutron interferometry with perfect crystal beam-splitters holds the current record in matter-wave delocalization, separating the quantum wave packet by up to 7 cm. c, Modern atom interferometry achieves coherence times beyond two seconds with wave-packet separations up to 1.5 cm . d, Interference of two clouds of Bose-Einstein condensed diatomic lithium molecules. e, Kapitza-Dirac-Talbot-Lau interferometer for macromolecules.

superpuestos pero no amontonados 1



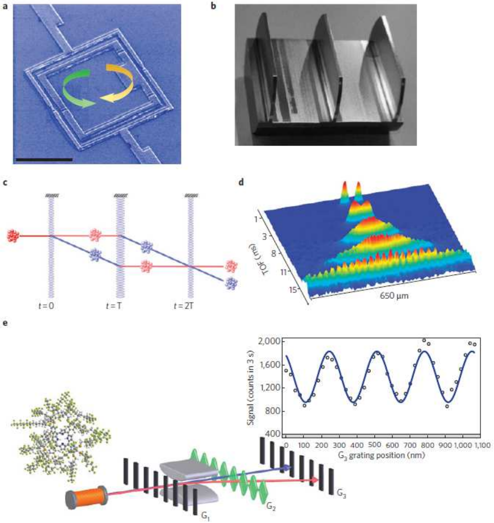
Superposition experiments. a, A flux qubit realizes a quantum superposition of left- and right-circulating supercurrents with billions of electrons contributing to the quantum state. b, Neutron interferometry with perfect crystal beam-splitters holds the current record in matter-wave delocalization, separating the quantum wave packet by up to 7 cm. c, Modern atom interferometry achieves coherence times beyond two seconds with wave-packet separations up to 1.5 cm . d, Interference of two clouds of Bose-Einstein condensed diatomic lithium molecules. e, Kapitza-Dirac-Talbot-Lau interferometer for macromolecules.

superpuestos pero no amontonados 1



Superposition experiments. a, A flux qubit realizes a quantum superposition of left- and right-circulating supercurrents with billions of electrons contributing to the quantum state. b, Neutron interferometry with perfect crystal beam-splitters holds the current record in matter-wave delocalization, separating the quantum wave packet by up to 7 cm. c, Modern atom interferometry achieves coherence times beyond two seconds with wave-packet separations up to 1.5 cm . d, Interference of two clouds of Bose-Einstein condensed diatomic lithium molecules. e, Kapitza-Dirac-Talbot-Lau interferometer for macromolecules.

superpuestos pero no amontonados 1



Superposition experiments. a, A flux qubit realizes a quantum superposition of left- and right-circulating supercurrents with billions of electrons contributing to the quantum state. b, Neutron interferometry with perfect crystal beam-splitters holds the current record in matter-wave delocalization, separating the quantum wave packet by up to 7 cm. c, Modern atom interferometry achieves coherence times beyond two seconds with wave-packet separations up to 1.5 cm . d, Interference of two clouds of Bose-Einstein condensed diatomic lithium molecules. e, Kapitza-Dirac-Talbot-Lau interferometer for macromolecules.

historia de la superposición 1

- Jönsson, C. Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161**, 454-474 (1961). (Electron interference at several man-made fine columns)
- Zeilinger, A., Gähler, R., Shull, C. G., Treimer, W. and Mampe, W. Single- and double-slit diffraction of neutrons. Rev. Mod. Phys. **60**, 1067-1073 (1988).
- Keith, D. W., Schattenburg, M. L., Smith, H. I. and Pritchard, D. E. Diffraction of atoms by a transmission grating. Phys. Rev. Lett. **61**, 1580-1583 (1988).
- Carnal, O. and Mlynek, J. Young's double-slit experiment with atoms: a simple atom interferometer. Phys. Rev. Lett. **66**, 2689âĂŞ2692 (1991).
- Arndt, M. et al. Wave-particle duality of C_{60} molecules. Nature **401**, 680-682 (1999)

historia de la superposición 1

- Jönsson, C. Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161**, 454-474 (1961). (Electron interference at several man-made fine columns)
- Zeilinger, A., Gähler, R., Shull, C. G., Treimer, W. and Mampe, W. Single- and double-slit diffraction of neutrons. Rev. Mod. Phys. **60**, 1067-1073 (1988).
- Keith, D. W., Schattenburg, M. L., Smith, H. I. and Pritchard, D. E. Diffraction of atoms by a transmission grating. Phys. Rev. Lett. **61**, 1580-1583 (1988).
- Carnal, O. and Mlynek, J. Young's double-slit experiment with atoms: a simple atom interferometer. Phys. Rev. Lett. **66**, 2689âĂŞ2692 (1991).
- Arndt, M. et al. Wave-particle duality of C_{60} molecules. Nature **401**, 680-682 (1999)

historia de la superposición 1

- Jönsson, C. Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161**, 454-474 (1961). (Electron interference at several man-made fine columns)
- Zeilinger, A., Gähler, R., Shull, C. G., Treimer, W. and Mampe, W. Single- and double-slit diffraction of neutrons. Rev. Mod. Phys. **60**, 1067-1073 (1988).
- Keith, D. W., Schattenburg, M. L., Smith, H. I. and Pritchard, D. E. Diffraction of atoms by a transmission grating. Phys. Rev. Lett. **61**, 1580-1583 (1988).
- Carnal, O. and Mlynek, J. Young's double-slit experiment with atoms: a simple atom interferometer. Phys. Rev. Lett. **66**, 2689âĂŞ2692 (1991).
- Arndt, M. et al. Wave-particle duality of C_{60} molecules. Nature **401**, 680-682 (1999)

historia de la superposición 1

- Jönsson, C. Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161**, 454-474 (1961). (Electron interference at several man-made fine columns)
- Zeilinger, A., Gähler, R., Shull, C. G., Treimer, W. and Mampe, W. Single- and double-slit diffraction of neutrons. Rev. Mod. Phys. **60**, 1067-1073 (1988).
- Keith, D. W., Schattenburg, M. L., Smith, H. I. and Pritchard, D. E. Diffraction of atoms by a transmission grating. Phys. Rev. Lett. **61**, 1580-1583 (1988).
- Carnal, O. and Mlynek, J. Young's double-slit experiment with atoms: a simple atom interferometer. Phys. Rev. Lett. **66**, 2689âĂŞ2692 (1991).
- Arndt, M. et al. Wave-particle duality of C_{60} molecules. Nature **401**, 680-682 (1999)

historia de la superposición 1

- Jönsson, C. Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161**, 454-474 (1961). (Electron interference at several man-made fine columns)
- Zeilinger, A., Gähler, R., Shull, C. G., Treimer, W. and Mampe, W. Single- and double-slit diffraction of neutrons. Rev. Mod. Phys. **60**, 1067-1073 (1988).
- Keith, D. W., Schattenburg, M. L., Smith, H. I. and Pritchard, D. E. Diffraction of atoms by a transmission grating. Phys. Rev. Lett. **61**, 1580-1583 (1988).
- Carnal, O. and Mlynek, J. Young's double-slit experiment with atoms: a simple atom interferometer. Phys. Rev. Lett. **66**, 2689âĂŞ2692 (1991).
- Arndt, M. et al. Wave-particle duality of C_{60} molecules. Nature **401**, 680-682 (1999)

historia de la superposición 2

Real-time single-molecule imaging of quantum interference, 25 MARCH 2012 | DOI: 10.1038/NNANO.2012.34, Nature Nanotechnology

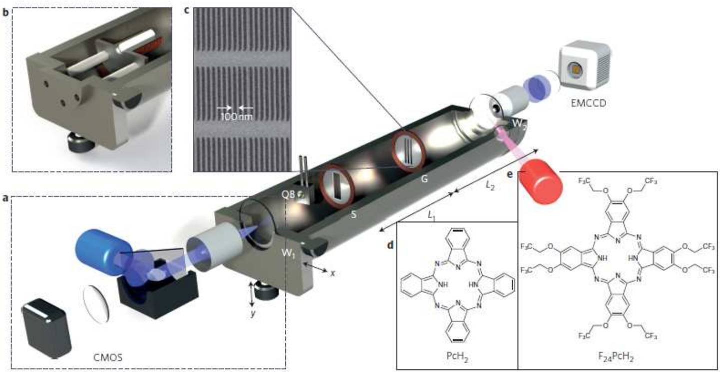


Figure 1 | Set-up for laser-evaporation, diffraction and nano-imaging of complex molecules. a, Thermolabile molecules are ejected by laser micro-evaporation. A blue diode laser (445 nm, 50 mW) is focused onto window W_1 to evaporate the molecules coated on its inner surface. A CMOS camera and a quartz balance (QB) monitor the evaporation area and the molecular flux. **b**, Stable molecules can be evaporated in a Knudsen cell. The collimation slit S defines the beam coherence. The molecular beam divergence is further narrowed by the width of the diffraction grating G. **c**, Electron micrograph showing that the grating is nanomachined into a 10-nm-thin SiN_x membrane with a period of $d = 100$ nm. The vacuum system is evacuated to 1×10^{-8} mbar. Molecules on quartz window W_2 are excited by a red diode laser (661 nm). High-resolution optics collects, filters and images the light onto an EMCCD camera. **d**,**e**, The molecules for this study: phthalocyanine PcH_2 ($C_{32}H_{18}N_8$, mass $m = 514$ AMU, number of atoms $N = 58$, **d**) and its derivative $F_{24}PcH_2$ ($C_{48}H_{26}F_{24}N_8O_8$, $m = 1{,}298$ AMU, $N = 114$, **e**). The mass, atomic number and internal complexity of $F_{24}PcH_2$ are approximately twice those of PcH_2.

historia de la superposición 3

Real-time single-molecule imaging of quantum interference, 25 MARCH 2012 | DOI: 10.1038/NNANO.2012.34, Nature Nanotechnology

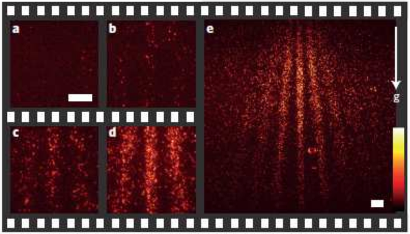


Figure 3 | Build-up of quantum interference. a-e, Selected frames from a

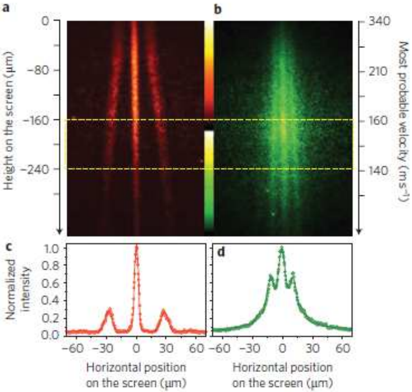
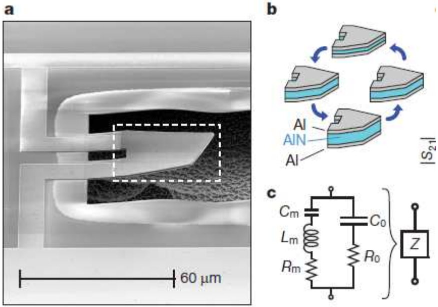


Figure 4 | Comparison of interference patterns for PcH_2 and $F_{24}PcH_2$.

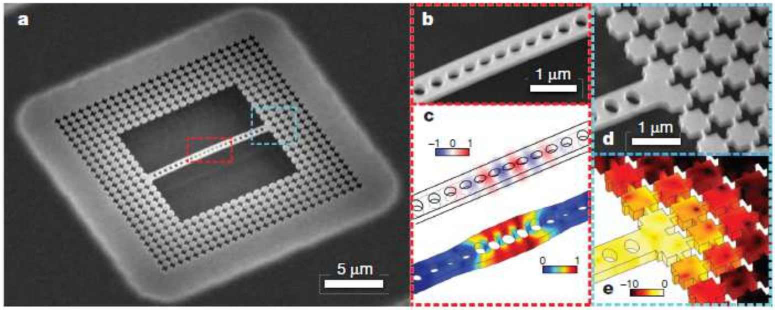
historia de la superposición 4

Quantum ground state and single-phonon control of a mechanical resonator, Nature **464**, 697 (2010)



historia de la superposición 5

Laser cooling of a nanomechanical oscillator into its quantum ground state, Nature **478**, 89 (2011)



Optomechanical resonator with phononic shield. a, Scanning electron microscope (SEM) image of the patterned silicon nanobeam and the external phononic bandgap shield. b, Enlarged SEM image of the central cavity region of the nanobeam. c, Top: normalized electric field (colour scale) of the localized optical resonance of the nanobeam cavity, simulated using the finiteelement method (FEM).

dos formas de hacer las cosas

- Of the various concrete schemes which have been proposed with a view to resolution of the measurement problem, by far the best-developed one is that associated with the names of Ghirardi, Rimini, Weber and Pearle (GRWP).
- As currently constructed, the theory contains two adjustable parameters: a length scale (a) which determines the minimum difference in position between two or more branches which is necessary to trigger the reduction process, and a quantity (λ) which characterizes the "efficiency" of this process, as measured by the rate at which a superposition state of a microscopic object such as an electron takes place
- In the current version of the theory the parameters a and λ are tentatively fixed at $\approx 10^{-5}$ cm and $\approx 10^{-16} s^{-1}$ respectively, and it seems that they could not be varied by many orders of magnitude from those values without leading either to a contradiction with the predictions of QM at the atomic level or to a failure to reduce macroscopic-level superpositions over typical "human" timescales.

dos formas de hacer las cosas

- Of the various concrete schemes which have been proposed with a view to resolution of the measurement problem, by far the best-developed one is that associated with the names of Ghirardi, Rimini, Weber and Pearle (GRWP).
- As currently constructed, the theory contains two adjustable parameters: a length scale (a) which determines the minimum difference in position between two or more branches which is necessary to trigger the reduction process, and a quantity (λ) which characterizes the “efficiency” of this process, as measured by the rate at which a superposition state of a microscopic object such as an electron takes place
- In the current version of the theory the parameters a and λ are tentatively fixed at $\approx 10^{-5}$ cm and $\approx 10^{-16}s^{-1}$ respectively, and it seems that they could not be varied by many orders of magnitude from those values without leading either to a contradiction with the predictions of QM at the atomic level or to a failure to reduce macroscopic-level superpositions over typical “human” timescales.

dos formas de hacer las cosas

- Of the various concrete schemes which have been proposed with a view to resolution of the measurement problem, by far the best-developed one is that associated with the names of Ghirardi, Rimini, Weber and Pearle (GRWP).

- As currently constructed, the theory contains two adjustable parameters: a length scale (a) which determines the minimum difference in position between two or more branches which is necessary to trigger the reduction process, and a quantity (λ) which characterizes the "efficiency" of this process, as measured by the rate at which a superposition state of a microscopic object such as an electron takes place

- In the current version of the theory the parameters a and λ are tentatively fixed at $\approx 10^{-5}$ cm and $\approx 10^{-16} s^{-1}$ respectively, and it seems that they could not be varied by many orders of magnitude from those values without leading either to a contradiction with the predictions of QM at the atomic level or to a failure to reduce macroscopic-level superpositions over typical "human" timescales.

primera forma

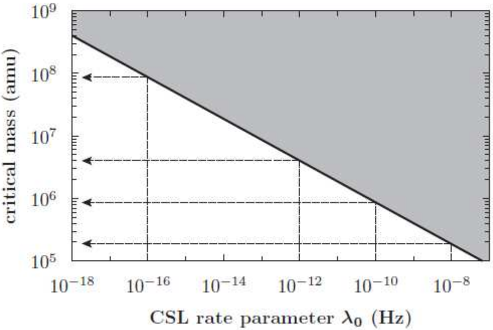
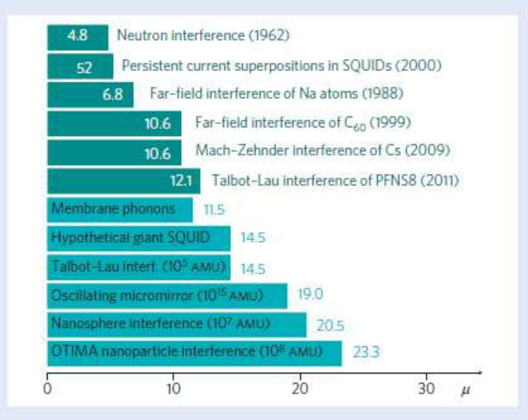


FIG. 1. Critical mass m_c for testing continuous spontaneous localization (CSL) as a function of the localization rate λ_0, assuming the geometry of the proposed experiment with $N = 2$. The shaded area indicates the parameter region where interference should be unobservable according to the CSL model. The dashed arrows mark the critical masses associated with reasonable estimates for the lower bound of λ_0 [6,7].

el futuro de la primera forma



segunda forma

- Penrose has suggested that collapse of a quantum superposition into one of its branches takes place as soon as the gravitational self-energy associated with the different mass distribution in the branches in question exceeds that of a single graviton
- no prediction of anything at all!!!!!

segunda forma

- Penrose has suggested that collapse of a quantum superposition into one of its branches takes place as soon as the gravitational self-energy associated with the different mass distribution in the branches in question exceeds that of a single graviton
- no prediction of anything at all!!!!!