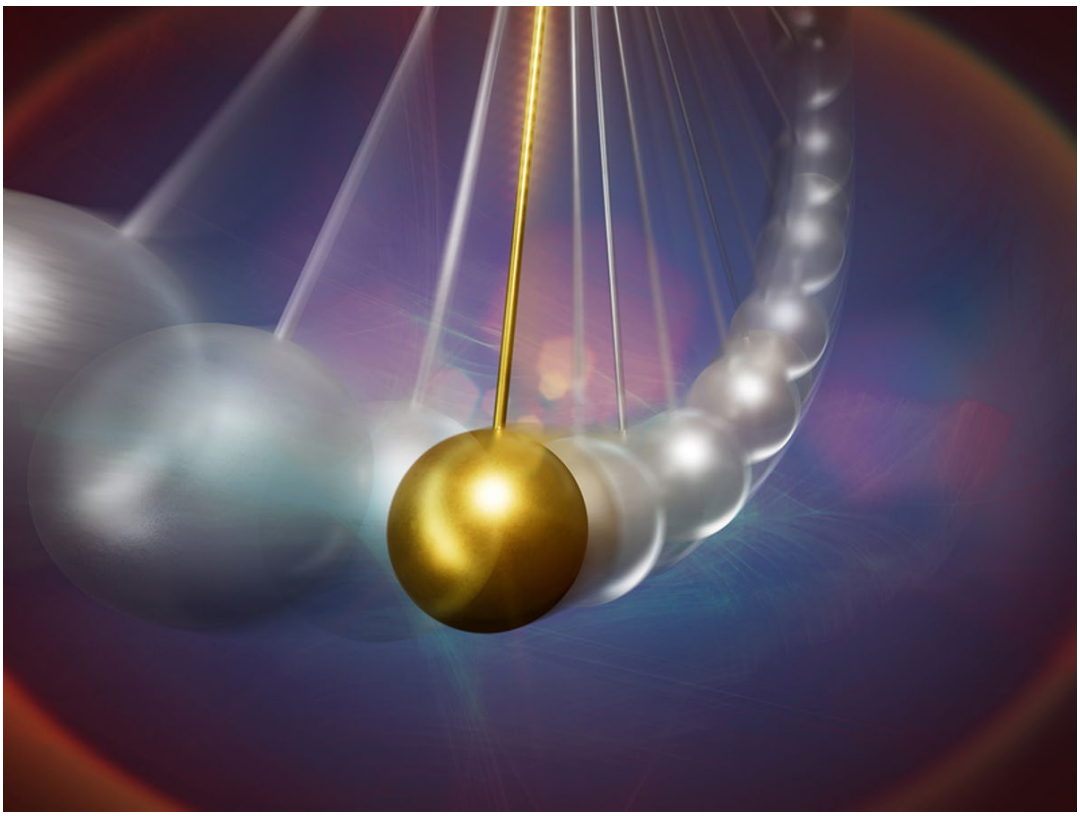
NEWSLETTER N.3, March 2024



An illustration representing Schrödinger's Pendulum. Credit: Mark Ross Studios. Image used for the press article "Schrödinger's Pendulum Experiment Will Search for the Quantum Limit" by Tim Folger

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Update of work done

Regular scientific meetings

QuCoM experimentalists hold regular online meetings every second Tuesday per month. They discuss progress on experimental realisations of gravity and quantum experiments. At both experiment sites, Leiden and Southampton, there are setups which are used to detect gravity with levitated masses. These experiments are cryogenic and involved advanced vibration isolation techniques. The discussions are typically about improvements of particle trap designs to reach high quality factors for levitated particle, pick up the motion of particles in the trap with directional sensitivity, materials science issues with traps and particles as well as preparation procedures of traps.

For instance, Leiden are using tantalum superconductors and asymmetric shaped particles to preferentially detect selected oscillation modes, while Southampton is using lead traps and mostly spherical particles. Experimentalists also discuss techniques and protocols to acquire data of the motion of levitated particles for highly sensitive force and acceleration detection as well as manipulation techniques to prepare selected states of motion, such as squeezed and cooled thermal states. The intermediate goal is to achieve thermal noise limited motional modes at the temperature of the cryogenic environment.

Presently, most modes are still driven and therefore heated by vibrations coupling into the particle motion. The best results have been achieved with a passive cryogenic system to be close to the thermal noise limit at 300 mK at Southampton. Therefore, vibration isolation strategies are discussed, and knowledge is shared for inverted pendulum GAS filters and other spring-mass type vibration isolation approaches. Leiden have the most advanced setup on vibration isolation while using a pulsed tube cooled cryostat. A creative idea is to use a liquid-based vibration damper for future improved isolation at low frequencies.

The QuCoM team is also, with occasional participation from theorists across the project team, discussion different ideas for setting up gravity experiments with the source mass implemented inside the cryostat, which will allow to reduce the size of the source mass significantly and likely below the current smallest mass gravity measurement achieved. The main idea is still to use close to resonance excitation of the source mass to enhance detection sensitive and use some sort of mass modulation of the source mass inside the cryo. Rotation based platforms as well as linear modulation systems are under consideration.

An overarching discussion is about the reduction of systematic effects in gravity experiments and one investigated approach is to consider a higher temperature (4K) experiment which is improved on systematics of mass and position accuracy. This is under development at Southampton.

Dissemination on general press

Partner of the Consortium have put efforts in activating links and contacting the general press with the aim of giving visibility and increasing awareness of the project.

The target group of the communication through popular press is, by definition, the largest general public. The style of the articles on the popular press is generally easy to read and understand for the average reader, with a limited use of scientific terms, many examples, analogies and metaphors. Given the topic of the QuCoM project, seemingly very far from people’s every-day life, articles often try to stir the audience's imagination and emotions. In a few cases, articles focused on a person participating in the project to make

the issue more human-cantered and draw the attention of the reader to a person's efforts and work rather than to the topic.

The popular press articles related to the project are stored on the QuCoM Website in the section 'Dissemination' at the link https://qucom.eu/press/.

In the aftermath of the publication of the paper "Measuring gravity with milligram levitated masses" (https://www.science.org/doi/10.1126/sciadv.adk2949) on *Science Advances* by Tim M. Fuchs, Dennis G. Uitenbroek, Jaimy Plugge, Noud Van Halteren, Jean Paul Van Soest, Andrea Vinante, Hendrik Ulbricht and Tjerk H. Oosterkamp, University of Southampton published a press release to launch the paper:

"Study used a sophisticated setup involving superconducting devices, known as traps, with magnetic fields, sensitive detectors and advanced vibration isolation. It measured a weak pull, just 30aN, on a tiny particle 0.43mg in size by levitating it in freezing temperatures a hundredth of a degree above absolute zero – about minus-273 degrees Celsius. The results open the door for future experiments between even smaller objects and forces, said Professor of Physics Hendrik Ulbricht also at the University of Southampton."
The press release was very effective in attracting the interest of the press, as shown by the following examples (see attachments for the press release and the full list of press articles).


Scientists closer to solving mysteries of universe after measuring gravity in quantum world

Published: 26 February 2024

Quantum gravity study

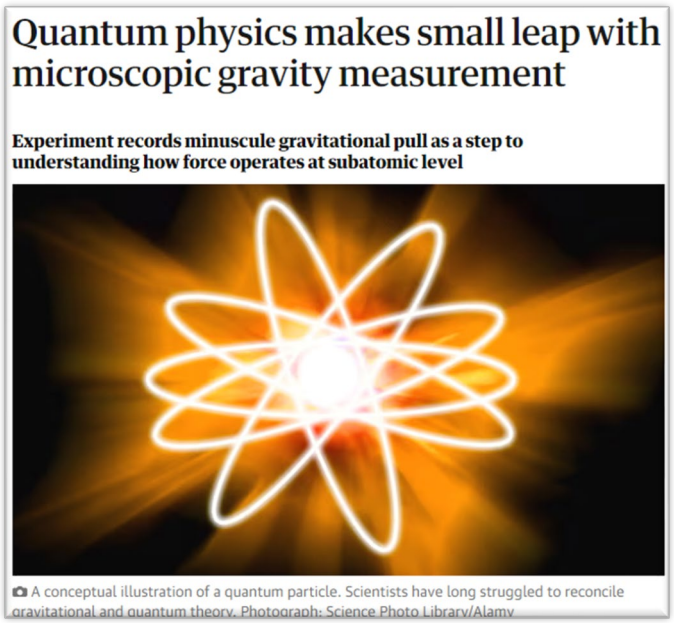
Scientists are a step closer to unravelling the mysterious forces of the universe after working out how to measure gravity on a microscopic level.

Experts have never fully understood how the force which was discovered by Isaac Newton works in the tiny quantum world.

Even Einstein was baffled by quantum gravity and, in his theory of general relativity, said there is no realistic experiment which could show a quantum version of gravity.

A screenshot of the press release on https://www.southampton.ac.uk/news/2024/02/quantum-gravity.page

Around the article there was a lot of press across the UK and international media outlets:



Quantum physics makes small leap with microscopic gravity measurement

Experiment records minuscule gravitational pull as a step to understanding how force operates at subatomic level

A conceptual illustration of a quantum particle. Scientists have long struggled to reconcile gravitational and quantum theory. Photograph: Science Photo Library/Alamy

The Guardian on 23rd February 2024: "Quantum physics makes small leap with microscopic gravity measurement", with 322.000.000 accesses reach[1]

BBC Science Focus

News Future tech Nature Space Human body Everyday science

Major quantum gravity breakthrough could spark new 'theory of everything'

Quantum gravity has long baffled scientists. Now, a breakthrough discovery could change physics forever - and answer our biggest questions about the Universe.

Image credit: University of Southampton

By Noa Leach

Published: February 23, 2024 at 8:00 pm

BBC Science Focus on 23rd February 2024: "Major quantum gravity breakthrough could spark new 'theory of everything", with reach 2.003.105

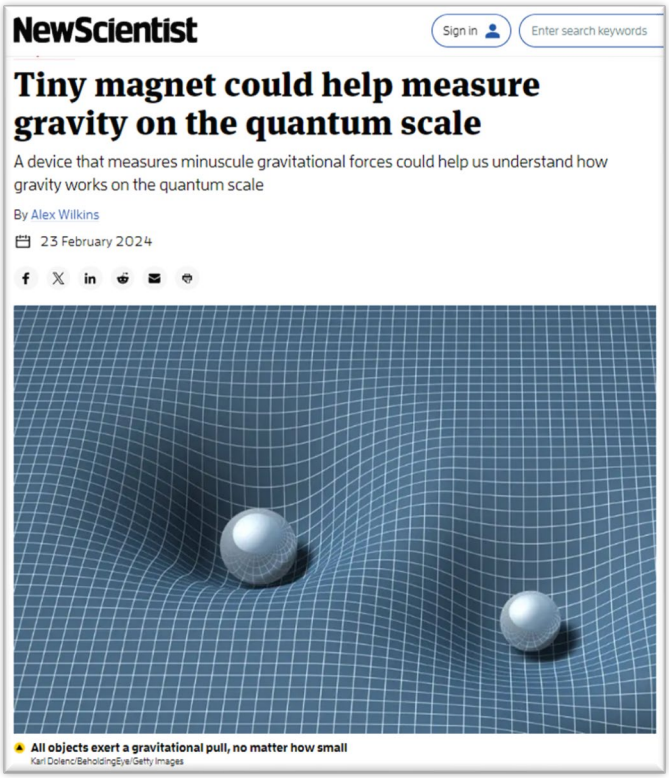
The Times on 23rd February 2024: "Was Einstein wrong? These British scientists think he might have been"

SCIENCE

Was Einstein wrong? These British scientists think he might have been

Research contradicts long-held belief that the effects of gravity cannot be measured at a subatomic scale

[1] *Source: UoS press office after one week post publication date.*


NewScientist

Sign in | Enter search keywords

Tiny magnet could help measure gravity on the quantum scale

A device that measures minuscule gravitational forces could help us understand how gravity works on the quantum scale

By Alex Wilkins

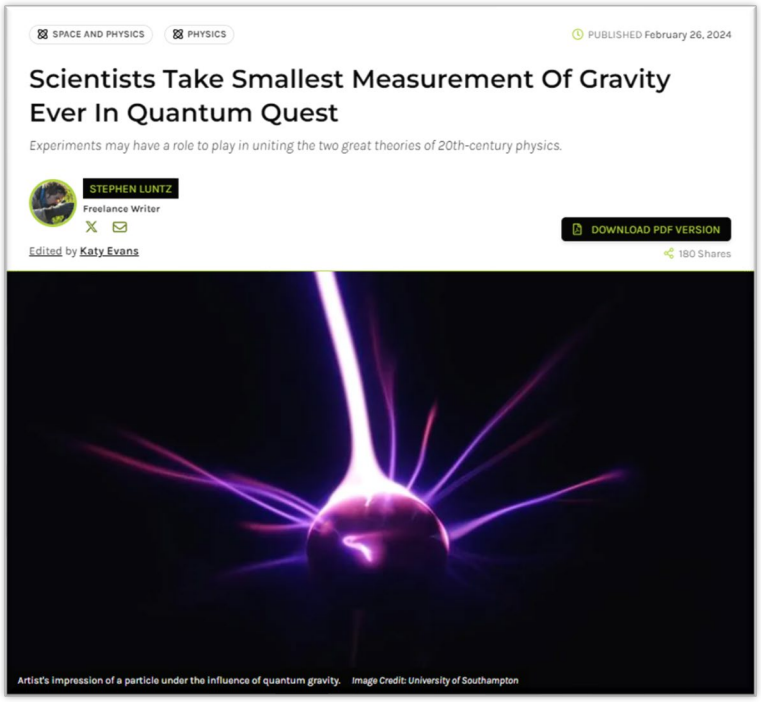
23 February 2024

All objects exert a gravitational pull, no matter how small

Karl Dolenc/BeholdingEye/Getty Images

New Scientist on 23rd February 2024: "Tiny magnet could help measure gravity on the quantum scale" with 4,672,235 accesses reach.

IFL Science on 26th February: "Scientists take smallest measurements of gravity ever in quantum quest", with reach 11,440,179


SPACE AND PHYSICS | PHYSICS

PUBLISHED February 26, 2024

Scientists Take Smallest Measurement Of Gravity Ever In Quantum Quest

Experiments may have a role to play in uniting the two great theories of 20th-century physics.

STEPHEN LUNTZ

Freelance Writer

Edited by Katy Evans

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Artist's impression of a particle under the influence of quantum gravity. Image Credit: University of Southampton

The news also appeared in a number of high-ranking science trade magazines:

- Space.com: https://www.space.com/gravity-quantum-theory-cosmic-mysteries
- Physics World: https://physicsworld.com/a/unifying-gravity-and-quantum-mechanics-without-the-need-for-quantum-gravity/
- Popular Mechanics: https://www.popularmechanics.com/science/a46936805/quantum-gravity/

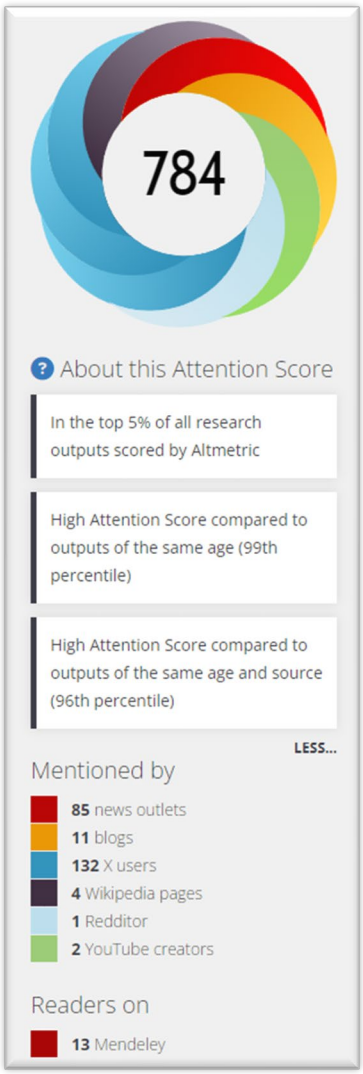
- Phys.org.: https://phys.org/news/2023-12-theory-einstein-gravity-quantum-mechanics.html#google_vignette

A total of 53 general press journals picked up the press release of the paper with a total estimated reach of **405,761,345 accesses**. A complete list of journals with links and reach can be found in attachment 1 to this report.

The topic of the article has also been covered by Sabina Hossenfelder in her YouTube blog which has attracted **236k views** as of 21st March 2024:

The coverage on the IAAA server with the impact metric shows that the article is in the **top 5% of all research outputs** scored by Altmetric. It is placed within the 99th percentile of the High Attention Score compared to outputs of the same age and within the 96th percentile in the High Attention Score compared to outputs of the same age and source. It was mentioned by 85 news outlets, 11 blogs, 132 X users, 4 Wikipedia pages and 2 YouTube creators.

https://scienceadvances.altmetric.com/details/160020380#twitter-demographics



Overview of attention for article published in Science Advances, February 2024

In addition to the attention received by the paper in Science Advances, the article "Mass-Independent Scheme to Test the Quantumness of a Massive Object", published on *Phys. Rev. Lett.* **132**, 030202 by Debarshi Das, Dipankar Home, Hendrik Ulbricht, and Sougato Bose has been in the spotlight.

On February 27, 2024 Scientific American published article with the title of "Schrödinger's Pendulum Experiment Will Search for the Quantum Limit" describing the QuCoM experiment: "For all its technical complexity, the experiment mimics a very simple phenomenon: the motion of a pendulum. An electromagnetic field drives the silica bead back and forth. Like a metronome, the bead regularly ticks from point A to point B and back again. As far as classical, nonquantum physics goes, that should be the end of the story. But a quantum pendulum should behave very differently. Its position will change depending on whether or not someone is watching: it might start at A but end up somewhere to the left or right of B. Call it Schrödinger's pendulum".
The communication of the QuCoM project via popular press articles has started with the announcement of the project's kick off in 2022 and has intensified during the first part of 2024 (second year of QuCoM's lifetime). A total of 54 general press journals wrote about QuCoM's papers and activities, provoking a consistent media interest on the Internet and social media. The Consortium members will steadily continue to develop this type of communication to the general public through the years 2 to 3 of QuCoM.

Review Report

On November 20, 2023 the Consortium convened with the Project Officer and 3 chosen monitors for a planned Review Meeting. The results of the review were shared in mid-March 2024 with an excellent overall assessment feedback. The report says that "*this is an excellent consortium ultimately addressing very fundamental questions in physics, yet with a potential for innovation in the technology used in experiments. The project has advanced well in its first year, with a swift start benefiting from pre-existing activities by many of the consortium members. Good progress has been achieved in all three scientific work packages, and the project runs smoothly including the collaboration between the various academic and commercial consortium members*."
The reviewers confirmed that "*scientific quality of the results is high, as clearly documented by several papers published in peer-reviewed, high-profile journals. Very likely, QuCoM will have sufficiently large impact on the scientific community of quantum physics, and optical and magnetic trapping and controlling. There is a clear plan for data management, communication, dissemination and exploitation. There has already been extensive dissemination via different channels and various audiences (from general audience to specialists). There is a well-structured and clear website with all the relevant information about QuCoM. There were no significant implementation issues or major deviations. The project will likely provide results with significant immediate or potential impact in the next reporting period*."
The feedback on the report was also useful in term of recommendations: "*The potential exploitation of such innovations should be supported throughout the project by a proper exploitation strategy, as well as communication, dissemination and exploitation-oriented activities*". "*In order to maximise its impact, it is recommended the consortium makes an effort to engage the broader public (through public talks and online channels) for the important scientific frontier it is working on; as well as focuses on generating and protecting innovative technologies*".
The Consortium wishes to thank the Reviewers and the Project Officer for the assistance and the useful comments.

Publications

Authors	Title	Journal	Volume	Pages	Year
Gianani, Ilaria; Belenchia, Alessio; Gherardini, Stefano; Berardi, Vincenzo; Barbieri, Marco; Paternostro, Mauro	Diagnostics of quantum-gate coherences deteriorated by unitary errors via end-point-measurement statistics	*Quantum Sci. Technol.*	8	045018	2023
Bartolomeo, Giovanni Di; Vischi, Michele; Cesa, Francesco; Wixinger, Roman; Grossi, Michele; Donadi, Sandro; Bassi, Angelo	Noisy gates for simulating quantum computers	*Phys. Rev. Research*	5	043210	2023
Innocenti, L.; Lorenzo, S.; Palmisano, I.; Ferraro, A.; Paternostro, M.; Palma, G. M.	Potential and limitations of quantum extreme learning machines	*Commun Phys,*	6	118	2023
Hernández-Gómez, Santiago; Gherardini, Stefano; Belenchia, Alessio; Trombettoni, Andrea; Paternostro, Mauro; Fabbri, Nicole	Experimental signature of initial quantum coherence on entropy production	*npj Quantum Inf*	9	86	2023
Das, Debarshi; Home, Dipankar; Ulbricht, Hendrik; Bose, Sougato	Mass-Independent Scheme to Test the Quantumness of a Massive Object	*Phys. Rev. Lett.*	142	030202	2024
Figurato, Laria; Bassi, Angelo; Donadi, Sandro	On the testability of the Károlyházy model	*New J. Phys.*	26	013001	2024
Blair, S.; Zicari, G.; Belenchia, A.; Ferraro, A.; Paternostro, M.	Nonequilibrium quantum probing through linear response	*Phys. Rev. Research*	6	013152	2024
Wardak, Jakub; Georgescu, Tiberius; Gasbarri, Giulio; Belenchia, Alessio; Ulbricht, Hendrik	Nanoparticle Interferometer by Throw and Catch	*Atoms*	*12*(2)	7	2024
Gaona-Reyes, José Luis; Menéndez-Pidal, Lucía; Faizal, Mir; Carlesso, Matteo	Spontaneous collapse models lead to the emergence of classicality of the Universe	*J. High Energ. Phys.*	*2024*	193	2024
Fuchs, Tim M.; Uitenbroek, Dennis G.; Plugge, Jaimy; van	Measuring gravity with milligram levitated masses	*Sci. Adv.*	*10*	Issue 8	2024

Halteren, Noud; van Soest, Jean-Paul; Vinante, Andrea; Ulbricht, Hendrik; Oosterkamp, Tjerk H.					
Barr, J; Zicari, G; Ferraro, A; Paternostro, M	Spectral density classification for environment spectroscopy	*Mach. Learn.: Sci. Technol.*	*5*	015043	2024
Bartolomeo, Giovanni Di; Carlesso, Matteo	Experimental bounds on linear-friction dissipative collapse models from levitated optomechanics	*New J. Phys.*	26	043006	2024

Dissemination activities

In the last 6 months, QuCoM members delivered seminars and talks as follows.

October – December 2023

Tests of the Quantum Superposition Principle

19/12/23

Event: Workshop "From Quantum Astronomy to Quantum Communications" Speaker: Angelo Bassi Place: University of Florence, Florence Date: 19 December 2023

Informational steady-states and conditional entropy production in continuously monitored systems

11/12/23

Event: CMONS - Workshop on continuously monitored quantum systems Speaker: Mauro Paternostro Place: Warsaw Date: 11 December 2023

Projective measurements can probe non-classical work extraction and time-correlations

07/12/23

Event: Group Seminar Speaker: Alessio Belenchia Place: University of Palermo, Palermo (Italy) Date: 7 December 2023

Quantum neuromorphic approach for efficient sensing of gravity-induced entanglement

05/12/23

Event: Pursuing Quantum Sensing for Reliable Roadmaps Worshop Speaker: Mauro Paternostro Place: ENEA – Frascati Research CentreVia Enrico Fermi 45 - 00044 Frascati (Roma) Date: 5 December 2023

Entanglement – le correlazioni quantistiche

01/12/23

Event: Public seminar Speaker: Angelo Bassi Place: Politecnico di Torino, Torino Date: 1 December 2023

Testing the foundations of quantum mechanics in space

23/11/23

Event: Physics Colloqium Speaker: Matteo Carlesso Place: University College Dublin, Ireland Date: 23 November 2023

Testing the foundations of quantum mechanics with levitated mechanical systems

08/11/23

Event: John Bell Day Lecture 2023 Speaker: Hendrik Ulbricht Place: Online (QUB) Date: 8 November 2023

Quantum neuromorphic approach for efficient sensing of gravity-induced entanglement

10/10/23

Event: New Trends in Nonequilibrium Statistical Mechanics 2nd Course Speaker: Mauro Paternostro Place: Erice - ETTORE MAJORANA FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE Date: 10 October 2023

January – March 2024

Quantum Communication programs in Europe, Italy and Trieste

21/03/24

Event: 1st Australian Quantum Communication Forum Speaker: Angelo Bassi Place: Australian Academy of Sciences, Canberra Date: 21 March 2024

Testing Fundamental Physics by Levitated Mechanics

01/03/24

Event: seminar at QSNET consortium Speaker: Hendrik Ulbricht Place: University of Sussex Date: 26 February 2024

Testing collapse models in lab and space

22/02/24

Event: Laws of Nature Speaker: Matteo Carlesso Place: Online Date: 22 February 2024

Testing for gravity in quantum systems by optomechanics: Ideas & experimental challenges

04/02/24

Event: Frontiers of Quantum Mechanics Speaker: Hendrik Ulbricht Place: Physikzentrum Bad Honnef Date: 4 February 2024

Decoherence due to vacuum fluctuations?

25/01/24

Event: Laws of Nature Speaker: Anirudh Gundhi Place: Online Date: 25 January 2024

Informational steady-states and conditional entropy production in continuously monitored systems

18/03/24

Event: Non-equilibrium Quantum Many Body Systems 2024 Speaker: Mauro Paternostro Place: Institute Henry Poincarè, Paris Date: 18 March 2024

Testing Fundamental Physics by Levitated Mechanics

26/02/24

Event: lecture Speaker: Hendrik Ulbricht Place: St Swinton school, Winchester, UK Date: 22 February 2024

Distinguishing between redundancy and consensus when quantifying quantum objectivity

21/02/24

Event: Quantum Information and Quantum Computing Seminars Speaker: Diana Chisholm Place: online Date: 21 February 2024

Non-quantum effects on quantum systems make particles diffuse

31/01/24

Event: Quantum West Speaker: Angelo Bassi Place: San Francisco Date: 31 January 2024

The quantum-to-classical transition from the dynamical collapse models' perspective

11/01/24

Event: Gravitation and Mathematical Physics Group Seminar Speaker: José Luis Gaona Reyes Place: CINVESTAV-IPN, Mexico City, Mexico Date: 11 January 2024