Quantum reality as the sum of all constraints - ID: 21333

Type of Funding Request: Full Proposal
Status of this Funding Request: Under Review

Instructions:

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Funding Request Info

Intro

Applicants Response to Bounce Questions:

Summary

Project title: Quantum reality as the sum of all constraints

Executive Summary:

As a scientific theory, quantum mechanics enjoys the unquestioned success of very accurately describing and predicting the outcome of experiments in a wide range of areas, with even its most counter-intuitive predictions never having been contradicted. The problem of the reconciliation of quantum mechanics with the theory of gravity, while being fundamental, is somewhat irrelevant on the scale of events likely to be directly accessible for experimental analysis in the foreseeable future. As long as quantum mechanics was only applied to the statistical properties of microsystems (atoms and subatomic particles), its diverse philosophical interpretations would largely be considered: by the people as equally absurd, by philosophers as equally valid, and by physicists as equally irrelevant. Now, with the routine direct experimental realization of quantum effects on the scale of macroscopic solid state quantum bits, the problem of reality in quantum mechanics is at its most pressing. In tackling the problem, we will try to follow Duns Scotus' dictum, that even God cannot create a self-contradiction.

We will develop the theoretical viewpoint of quantum reality as the truth, which satisfies the absolute maximum number of logical constraints which can be imposed, using as a test a quantum metamaterial, an artificial medium comprised of superconducting quantum bits) through which and electromagnetic wave can propagate. This is a realistic model of an extended quantum object, which can be literally observed through optical or quasioptical means.

We will analyze the predictions of the theory with an emphasis of the directly observable properties of such an object, and on the limits of compatibility of mutually irreconcilable “views” of it suggested by standard quantum mechanics. We will bring these results to the attention of leading experimentalists and of the philosophers, in order to clarify the view on the ontology of quantum mechanics and its possible limits.

Relation to Sir John Templeton's Donor Intent:

Knowledge is good in itself; knowledge of reality at its deepest known level is an urge as deep as it is noble.

The proposed project aligns with the Core Funding Areas of The John Templeton Foundation in that it is, on a very fundamental level, targeted towards increasing the understanding of the “basic forces, concepts, and realities” governing the universe and humankind’s place in it. This project takes a contrarian viewpoint in approaching established theory (in this case the Copenhagen interpretation of quantum mechanics) and seeks to develop new, transcendent metaphysical ways of viewing the quantum states of matter. In every sense this would involve the development of “new spiritual information”, which would be made widely available.

Furthermore, in the widest possible sense, we are directly approaching the Big Question Number Two: How can we best study macro-scale phenomena in terms of the micro-scale processes from which they emerge?

We aim to achieve a deeper understanding of the nature of reality as it emerges from phenomena only observable indirectly, to what can be (almost literally) seen.

The scope of existing work undertaken by the applicant in the field of quantum metamaterials will be extended to develop new perspectives on quantum reality.
The traditional funding streams are averse to funding the fundamental and philosophically significant aspects of the team's research.

Dialogue with both the scientific and the wider community is at the heart of this project. Significant new material will be published designed to engage not only the research community, but also a more general audience. Events will be staged that will seek to broaden the uptake and understanding of quantum metaphysics.

The project will have significant impact on the development of philosophical thought. It will help bring philosophers back to the primary questions about the world and our ability to understand it.

Project

Strategic Opportunity or Promise:

The need for thorough investigation of the ontological status of quantum reality is currently being directly and increasingly pressingly imposed on the physics and more wider scientific communities by the accelerating nature of developments in a number of new technologies (quantum computing being the most prominent and hyped), such that possible impacts are attracting attention far outside of those undertaking scientific research.

In the past, as quantum materials have not been within touching distance of the experimentalist, understanding their ontological status has not been of pressing urgency to physicists, let alone to society. However, from the current point of view of science, not having a consistent ontological understanding of our activity is no longer irrelevant: it can and will influence our activities and to an increasing degree, will determine the success or failure of our research program (at the very least).

We propose a direct investigation of the ontological status of quantum reality, to be aligned as closely as possible to the now routine experimental manipulations with very large (on the atomic scale) but still quantum-mechanical objects. The large amount of existing reliable experimental data and a well developed theoretical formalism in this area gives us confidence that our project will bring significant progress in this direction.

To the best of our knowledge, this aspect of research into solid state quantum information processing is not receiving enough attention, because of the perceived irrelevance of the outcome. However, we strongly believe that the results would be important both for physics and philosophy. The current ignorance of philosophy by physicists, or at best lip service to some philosophical doctrines (mostly positivist), stems from “the miraculous impotence of philosophy”, i.e. its irrelevance to the progress of science over the last century, as well as from the postmodernist neglect of ontology and suspicion of science, which afflicts much of philosophy itself. To give both sides something in common to think about, especially an issue as fundamental as the quantum-classical transition and the nature of reality, is as ambitious and worthy a goal as any physicist (or philosopher) could envision.

Big Questions:

Can the “measurement problem” in quantum physics be resolved?

Project Description: TFProjectDescription_13-SEP3-Revised Jan25-AZ.pdf

Theory of Change:

To date, all of the philosophical interpretations of quantum mechanics have not make any difference to the status quo, since they affected neither the character of predictions made by the theory, nor the agreement of these predictions with experimental data. The seemingly huge gap between the microscopic scale, where quantum mechanics was supposed to operate, and the macroscopic scale, on which our senses and conscience operates, provided a convenient cover for the essentially irreconcilable differences between the two sets of rules.

The development of such quantum coherent devices as superconducting qubits not only confirmed that quantum rules apply on a much bigger scale than would be comfortable for such a complacent worldview, but also promises a realization of macroscopic, but quantum coherent, objects capable of realizing Schroedinger's cat-like behaviour on a scale directly accessible to the human senses.

Research in this direction will either discover some fundamental scale restrictions on the quantum laws - a stupendous development for physics - or will force us to incorporate quantum rules in our worldview on the human scale of operation - no less shift in the ontology.

Our project is directed towards the investigation of a class of physical systems where one of these changes is most likely to be discovered: quantum metamaterials. We do not want to restrict our research to a narrow technical aspect, or to reduce it to a fashionable, "interdisciplinary" discussion, which makes everybody involved feel clever and important, but does not actually lead anywhere. Instead we

want to reach out across the aisle to discuss specific, verifiable, "visible" results, and their meaning to our understanding of the world.

Capacity for Success:

The PL has conducted research into the field of theoretical quantum information processing in the solid state for over ten years. During this time he has gathered successful experience in putting together and running large international collaborations, involving both theorists and experimentalists, and has acquired a global network of contacts and collaborators, giving him access to the most advanced experimental groups and facilities, such as at NEC (Tsukuba, Japan), IPHT(Jena, Germany), NPL and RHUL (London, UK), CTH (Gothenburg, Sweden), as well as to theoretical expertise and computational resources. The PL has authored and co-authored a number of research papers in such high-impact journals as “Science”, “Phys. Rev. Lett.” and “Phys. Rev. A,B”, which are widely cited by experts working on quantum computing, quantum mesoscopic physics, weak superconductivity, quantum transport and related areas. His graduate textbook “Quantum Theory of Many-Body Systems” is widely used and was translated into Japanese.

The PLs' interests include the philosophical problems of physics, and the problem of quantum ontology in particular, as well as the questions of the interaction between science and humanities and the public in general. At Loughborough the PL has developed an original undergraduate course on the history and philosophy of science and has been teaching this course since 2008.

The Pl has also organized an international workshop: “Quantum Technologies 2004” in Vancouver, attended by a number of top researchers in quantum information processing (from Canada, Germany, Japan, USA etc.), with special sessions accessible to the lay audience, and will use that experience in executing this project.

The Co-Is are experts of international standing in the field of quantum computing and quantum theory. One of them (SS) has under his belt several prestigious prizes and research fellowships. Together, The PL and SS have advanced, and are further developing the concept of quantum metamaterials, key to this project. After their initial paper on the subject (Rakhmanov AL, Zagoskin AM, Savel'ev S, et al., PRB 77 (2008) 144507) caused a certain stir, one of the world’s leading experimental groups (at NEC) decided to investigate. This resulted in a series of papers, where the PL is co-author, published in “Science” and “Phys. Rev. Lett.” in 2010:

Astafiev O, Zagoskin AM, Abdumalikov AA, et al., SCIENCE 327 (2010) 840
Astafiev OV, Abdumalikov AA, Zagoskin AM, et al., PRL 104 (2010) 183603
Abdumalikov AA, Astafiev O, Zagoskin AM, et al., PRL 104 (2010) 193601

Here, a single artificial atom (superconducting qubit) was placed in a one-dimensional waveguide. This “quantum proto-metamaterial” already demonstrated very unusual properties such as ideal switching, which brought attention from the wider public (http://physicsworld.com/cws/article/news/42385), but were nevertheless in full agreement with the theoretical predictions.

While the NEC and IPHT-Jena groups continue the experimental research (first trial samples of quantum metamaterial prototypes are currently being measured at the latter lab), the PL and his colleagues continue the development of the theoretical description. The PL is particularly well placed to undertake this activity at Loughborough due to the Department’s strong background and expertise in the relevant theoretical fields, as well as its connections to the School of Electrical Engineering (the PL is currently a co-applicant for an engineering grant from EPSRC, where some of tasks include the research of engineering applications of quantum metamaterials). The Department has a broad vision of physics and science and actively encourages interdisciplinary research. The PL is also, of course, fortunate in having SS and ME as collaborators.

Overall Project Timeline: Zagoskin_project_timeline_13SEP-REVISEDJan25-2011.xlsx

Results

Output

Output 1
What will be produced and how many?:

No less than two research articles in high-impact physics journals (e.g. Science, Phys. Rev. Lett.) by the close of the grant containing a quantitative theory of quantum metamaterials based on superconducting qubits and its experimentally verifiable predictions. One more will be published within a year after the close.

What will be delivered/reported?:

The texts of articles and their layman-accessible resumes will be delivered immediately after each publication.

Output 2
What will be produced and how many?:

A paper on the ontological aspects of the research will be produced and published in an internationally recognized journal by the close of the grant.

What will be delivered/reported?:

The texts of article and its layman-accessible resume will be delivered immediately after the publication.

Output 3
What will be produced and how many?:

The edited/reworked summary of the published research results will be made available online.

What will be delivered/reported?:

The summary will be delivered and made available online by the end of the project.

Outcome

Outcome 1
What will be different and which audience(s) will be affected? :

We will achieve a better theoretical understanding of the implications of quantum ontologies for experimentally accessible behaviour of macroscopic quantum objects.

What are the indicators of the difference? Quantify the changes that are likely to occur within and after the life of your project.:

We will have quantitative predictions for experiments, which could hopefully directly probe different quantum ontologies. We expect that other theoretical papers on the topic from independent teams will appear during or within a year after the close of the grant.

Outcome 2
What will be different and which audience(s) will be affected? :

Further experimental research, using our theory, will be undertaken in the field of quantum metamaterials.

What are the indicators of the difference? Quantify the changes that are likely to occur within and after the life of your project.:

Experimental evidence of quantum/classical transitions will become available. We expect that experimental research papers following our theoretical predictions/suggestions will be published within two years after the close of the grant.

Outcome 3
What will be different and which audience(s) will be affected? :

Discussion of the results between theorists, experimentalists and philosophers will take place.

What are the indicators of the difference? Quantify the changes that are likely to occur within and after the life of your project.:

Better understanding of the fundamental ontological implications of the possible realization of extended quantum objects will be achieved. It is possible that by the conclusion of this project, philosophers will take on this investigation independently. Independent papers on the ontological implications of our research will appear within three years after the grant's close.

Outcome 4
What will be different and which audience(s) will be affected? :

Students and laymen will have access to the specially attuned materials online.

What are the indicators of the difference? Quantify the changes that are likely to occur within and after the life of your project.:

The public will have access to the first-hand information about one of the key questions of modern science and philosophy. The project will obtain media coverage (research profiles in such journals as "New Scientist", "Physics World", "Physics Today", "Nature", "Science", "Scientific American" etc, as well as popular science web-sources) during and/or after the grant's close.

Enduring Impact:

This project can have a major long-term impact. If the research program undertaken in its framework leads to experimental results that either definitively refute or definitely confirm the existence of the absolute quantum-classical dichotomy, either outcome will be stupendous and will lead to a deep rethinking of our current view of the Universe and our place in it and (as a collateral advantage) to some interesting new technologies. The measure of success will be the eventual publication of a paper on experimental demonstration of either possibility; its independent confirmations; and - in case the absolute quantum-classical dichotomy exists - the reformulation of a more general theory, of which the current quantum theory will be a limiting case.

The project is structured to raise the public awareness of fundamental questions concerning the nature of the reality, and of the difference between a serious treatment of the subject and a quasi-scientific/pseudophilosophical approach to it. In the best-case scenario, there will appear serious treatments of the science and philosophy of the subject, written on a public-accessible level. Eventually the subject should make its way into the school curricula.

We hope that it will also make physicists and scientists in general pay due attention to the fundamental realities behind the equations - and turn philosophers from their current preoccupation with the questions of secondary and tertiary importance to the fundamental ontological and epistemological problems. Here the appearance of collaborative publications on this topic, produced by physicists and philosophers, would be a good indicator of the enduring impact of this project. Again, in the best case scenario the results will make its way to the curricula (this time at the university level).