



Foundational Questions
in Physics & Cosmology

TIME AND FOUNDATIONS:

REQUEST FOR PROPOSALS FOR RESEARCH ON THE NATURE OF
TIME AND OTHER FOUNDATIONAL QUESTIONS IN PHYSICS AND
COSMOLOGY

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I. WHO WE ARE

The Foundational Questions Institute (FQXi) is an independent, philanthropically funded grant-awarding non-profit organization.

Our mission is to catalyze, support, and disseminate research on questions at the foundations of physics and cosmology, particularly new frontiers and innovative ideas integral to a deep understanding of reality, but unlikely to be supported by conventional funding sources.

II. BACKGROUND

In the centuries since Galileo revolutionized human thought by insisting that physical phenomena be observed systematically and described mathematically, physics and cosmology have formed the bedrock of our understanding of the physical world, as well as the pre-eminent source of new insight into our deepest questions of reality. A few examples, now familiar but profoundly radical in their time, will suffice:

- ✎ Newton showed that most motions of earthly and nearby heavenly objects were well described by simple equations and a clockwork conception of space and time.
- ✎ Einstein realized that our conceptions of space and time must be fundamentally reworked, and that by doing so we may describe the structure of the entire observable universe within physical theory.
- ✎ The creators of quantum mechanics produced equations explicating reality on the smallest scales, but were forced to dispense with or generalize prior notions of causality, repeatability, and objectivity, in ways we still may not fully appreciate.

At FQXi, we believe that similar paradigm-shifting discoveries may now be occurring in physics and cosmology. Our mission is to support the researchers and outreach specialists who are developing and interpreting these coming revolutions.

Indeed, many giants of modern science – and their colleagues – were passionately concerned with and inspired by the deep philosophical implications of the novel notions of reality they were engaging. Moreover, their bold discoveries expanded rigorous science to encompass many previously ‘speculative’ or ‘philosophical’ matters.

Nonetheless, some – now as then – dismiss such matters as meaningless philosophy or empty metaphysics, encouraging colleagues to eschew such thinking and focus on concrete calculations. Most grant-awarding and research organizations institutionalize this pragmatic approach, primarily funding incremental investigations using known methods and familiar con-



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ceptual frameworks, rather than the uncertain and often interdisciplinary methods required to develop and comprehend prospective revolutions in physics and cosmology.

In addition to curtailing the potential for discovery, this mode of thinking greatly diminishes the excitement and meaning of modern science in the public consciousness; partly as a result of this, many otherwise well-educated people maintain either a pre-scientific worldview, or one informed by outdated concepts.

III. GOALS & PROGRAMMING

Given this context, FQXi offers grants programs that serve a three-fold purpose:

- ❧ To encourage and support rigorous, innovative, and influential scientific research and collaborations on foundational questions in physics and cosmology, which may have significant and broad implications for a deep understanding of reality;
- ❧ To redress incrementalism in research programming by establishing or expanding new 'islands' of understanding via flexible funding of high-risk, high-reward research in these areas;
- ❧ To provide the public with a deeper understanding of known and future discoveries in these areas, and their potential implications for our worldview.

In support of these goals, FQXi will offer grants of varying value to exceptional and rigorous scientific research proposals that meet the criteria described below.

FQXi will direct these grants through a Donor Advised Fund (DAF) at the Silicon Valley Community Foundation. FQXi will solicit and review grant applications, and on the basis of these reviews, FQXi will advise the DAF on what grants to make. After grants have been made by the DAF, FQXi will work with the DAF to monitor the grantee's performance via grant reports. In this way, researchers will continue to interact with FQXi, while the DAF interacts mostly with the researchers' institutes' administrative or grants management offices.

IV. FOCUS ON THE NATURE OF TIME

FQXi's programming encompasses both 'open' requests for proposals and more targeted programs in particular areas of thought. The current request for proposals targets research regarding "The Nature of Time". Some funds will also be made available for more general proposals of exceptional quality, as described below.



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The topic of Time is of both deep and broad interest for research in foundational questions in physics and cosmology. Science, and particularly physics, has produced dramatic insights into the nature of time. The theory of relativity is a striking example: engendered by thoughts of how to best synchronize moving clocks, it reveals that there is no unique notion of “now”. Careful consideration of time has likewise caused revolutions in physics, and may again do so. Indeed, the dramatically different treatments of time in quantum mechanics and in general relativity suggest to many researchers that a breakthrough in quantum gravity may require a new and deeper notion of time.

The concept of time is a crossroads at which thinkers of many backgrounds and disciplines meet, making it a topic that demands collaboration amongst researchers working in many different fields. FQXi can foster this collaboration using a concerted topical push into the subject area. Furthermore, a deep study and understanding of time’s nature is of widespread interest to the general public as well as the intellectual community. Deep or interesting research results could have significant impact on public thought, and will certainly provide a compelling lens through which to bring an understanding of foundational research to a wide audience. These points make clear that the nature of time is a perfect subject for FQXi support.

V. EVALUATION CRITERIA & PROJECT ELIGIBILITY

In our 2010 competition, grants totaling about \$2.0M will be available to researchers in academic and other non-profit institutions for projects up to two years in duration, beginning early January, 2011. Grant applications will be subject to a competitive process of external and confidential expert peer review similar to that employed by all major U.S. scientific funding agencies.

Proposals will be evaluated according to their **relevance** and **impact**.

☞ **Relevance:** Proposals should be topical, foundational, and unconventional.

- **Topical:** This RFP is limited to research in physics (mainly quantum physics, high energy ‘fundamental’ physics, and gravity), cosmology (mainly of the early universe) and closely related fields (such as astrophysics, astrobiology, biophysics, mathematics, complexity and emergence, and philosophy of physics). Proposals will be accepted in one of two categories:
 - a. Proposals of exceptional merit on all topics within the general FQXi purview, or
 - b. Research bearing directly on The Nature of Time. Appropriate research topics in this category will address questions such as (a longer list of questions is given in Appendix B):

- Can physics establish or deny the flow of time? If the flow of time is an illusion, how do we explain this illusion?
 - Are the laws of physics time-symmetric or time-reversible? If not, how does one explain the time symmetry of some physical laws and the asymmetry of others? Does the big bang explain the entropic arrow of time?
 - What do the theories of quantum mechanics and general relativity tell us about the nature of time? How do we reconcile their seemingly inconsistent conceptions of time?
 - Is the nature of time intrinsically different from that of space?
 - Can physical time be infinite?
- **Foundational:** This RFP is limited to research with potentially significant and broad implications for our understanding of the deep or “ultimate” nature of reality.
 - **Unconventional:** This RFP is intended to fill a gap, not a shortfall, in conventional funding. We wish to enable research that, because of its speculative, non-mainstream, or high-risk nature, would otherwise go unperformed due to lack of available monies. Thus, although there will be inevitable overlaps, an otherwise scientifically rigorous proposal that is a good candidate for an FQXi grant will generally *not* be a good candidate for funding by the NSF, DOE, etc. – and vice versa.
- 🔗 **Impact:** Proposals will be rated according to their expected scientific impact per dollar, taking all relevant factors into account, such as:
- Intrinsic intellectual merit, scientific rigor and originality
 - Potential for significant contribution to basic science relevant to the topic and a high *product* of likelihood for success and importance if successful (i.e., high-risk research can be supported as long as the potential payoff is also very high)
 - The likelihood of the research opening fruitful *new* lines of scientific inquiry
 - The feasibility of the research in the given time frame
 - The qualifications of the Principal Investigator and team with respect to the proposed topic
 - The part a grant may play in career development
 - Cost effectiveness: Tight budgeting is encouraged in order to maximize the research impact of the project as a whole, with emphasis on scientific return per dollar rather than per proposal

Because of the unconventional nature of the FQXi mission, we encourage part-time work (15% to 40%), in parallel with the scientist's usual research, rather than full-time appointments or studentships. Acceptable uses of grant funds include:

- Student or postdoctoral salary and benefits for part of the academic year
- Summer salary and teaching buyout for academics
- Support for specific projects during sabbaticals



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- Assistance in writing or publishing books
- Modest allowance for justifiable lab equipment, computers, publication charges, and other supplies
- Modest travel allowance
- Experimental equipment (keep in mind that while FQXi is very interested in experimental proposals, the total available funding means that funding for large equipment purchases will be unlikely.)
- Development of large workshops, conferences, or lecture series for professionals (Note that small programs of this type, and others costing less than US \$15K, are best supported by an FQXi Mini-Grant. Mini-Grant applications, however, are restricted to FQXi Members.)
- Development of outreach or educational programs for laypeople that disseminate knowledge regarding foundational questions in physics and cosmology (The impact criterion, in this case, will be judged on the proposal's ability to disseminate knowledge rather than develop it. Note that small programs of this type are best supported by an FQXi Mini-Grant. Mini-Grant applications, however, are restricted to FQXi Members.)
- Overhead of at most 15%

VI. APPLICATION PROCESS

Applications will be accepted electronically through a standard form on our website, fqxi.org, and evaluated in a two-part process, as follows:

I. INITIAL PROPOSAL – DUE June 14, 2010 – Must include:

- Specification of whether your proposal addresses the Nature of Time focus area, or the general FQXi purview
- A 300 – 500-word summary of the project, explicitly addressing why it is topical, foundational and unconventional
- A draft budget description not exceeding 200 words, including an approximate total cost over the life of the award and explanation of how funds would be spent
- A Curriculum Vitae for the Principal Investigator, which **MUST** be in PDF format, including:
 - Education and employment history
 - A list of references to five previous publications relevant to the proposed research and five additional representative publications
 - Full publication list

A review panel assembled by FQXi will screen each Initial Proposal according to the criteria in Section V. Based on their assessment, the Principal Investigator (PI) may be invited to submit a Full Proposal, on or about July 30, 2010, perhaps with feedback from FQXi on im-



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proving the proposal. Please keep in mind that however positive FQXi may be about a proposal at any stage, it may still be turned down for funding after full peer review.

2. FULL PROPOSAL – DUE September 30, 2010 – Must include:

- Cover sheet
- A 200-word project abstract, suitable for publication in an academic journal
- A project summary not exceeding 200 words, explaining the work and its significance to laypeople
- A detailed description of the proposed research, not to exceed 15 single-spaced 11-point pages, including a short statement of how the application fits into the applicant's present research program
- A detailed budget over the life of the award, with justification and utilization distribution (preferably drafted by the applicant's institution's grant officer or equivalent)
- Evidence of tax-exempt status of grantee institution, if other than a US university
- Names of 3 recommended referees
- Curricula Vitae for all project senior personnel, including:
 - Education and employment history
 - List of references to five previous publications relevant to the proposed research, and five additional representative publications
 - Full publication list
- A listing, for all project senior personnel, of all present and pending financial support, including project name, funding source, dates, amount, and status (current or pending)
- **For past FQXi Large Grant awardees only:** A 250-word statement explaining what was done with previous FQXi Large Grant funding and how that work ties in to the current proposal

Completed Full Proposals will undergo a competitive process of external and confidential expert peer review, evaluated according to the criteria described in Section V. A review panel of scientists in the relevant fields will be convened to produce a final rank ordering of the proposals, which will determine the grant winners, and make budgetary adjustments if necessary. Public award announcements will be made in early December, 2010.



APPENDIX A: FREQUENTLY ASKED QUESTIONS

Does FQXi have a preferred philosophical or scientific agenda?

No. We are equally interested in all proposals with great promise and talent falling within the FQXi purview and the parameters of the request for proposals.

Who is eligible for grants?

Researchers and outreach specialists working in academic and other non-profit institutions are eligible.

Can researchers from outside the U.S. apply?

Yes, applications will be welcomed from any country. However, payments from FQXi must comply with the U.S. Patriot Act. If compliance is a concern for your institution, please investigate your options with the appropriate personnel before investing time in writing a Full Proposal.

How and when do we apply?

Apply online at fqxi.org. Please submit an Initial Proposal by *June 14, 2010*. After screening, you may then be invited to submit a Full Proposal, due *September 30, 2010*. Please see Section VI for more information.

What kinds of programs and requests are eligible for funding?

- Student or postdoctoral salary and benefits for part of the academic year
- Summer salary and teaching buyout for academics
- Support for specific projects during sabbaticals
- Assistance in writing or publishing books
- Modest allowance for computer equipment, publication charges, or supplies, provided that these items are clearly justified in the proposal
- Experimental equipment (keep in mind that while FQXi is very interested in experimental proposals, the total available funding means that funding for large equipment purchases will be unlikely.)
- Modest travel allowance
- Development of large workshops, conferences, or lecture series (Note that small programs of this type, and others costing less than US \$15K, are best supported by an FQXi Mini-Grant. Mini-Grant applications, however, are restricted to FQXi Members.)
- Development of outreach or educational programs for laypeople that disseminate knowledge regarding foundational questions in physics and cosmology (The impact criterion, in this case, will be judged on the proposal's ability to disseminate knowledge rather



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than develop it. Note that small programs of this type are best supported by an FQXi Mini-Grant. Mini-Grant applications, however, are restricted to FQXi Members.)

- Overhead of at most 15%.

What is your policy on overheads?

The highest allowed overhead rate is 15%.

How will proposals be judged?

After screening of the Initial Proposal, applicants may be asked to submit a Full Proposal. All Full Proposals will undergo a competitive process of external and confidential expert peer review. An expert panel will evaluate and rank the reviews according to the criteria described in Section V.

Will proposals on the Nature of Time focus area be judged in the same pool as the more general proposals, and how much funding will go to each?

The majority of funds in this RFP are targeted to projects focusing on the Nature of Time. However, FQXi does not want to ignore exceptionally worthy projects on other topics and is thus making some portion of the funding available for these. Proposals in the 'Time' and 'General' categories will be ranked separately by the panel at both the initial and full proposal stages; due to the smaller funding and wider range of topics we expect that the 'General' category will be significantly more competitive.

Can you give me any guidance on my research proposal, and on whether or not our project fits within the funding vision?

Please see Appendix B below for example topics that appropriate research proposals will tackle. Occasionally, FQXi may provide feedback on Initial Proposals invited for a Full Proposal, and also limited advice during the preparation of the Full Proposal. Please keep in mind that however positive FQXi may be about a proposal at any stage, it may still be turned down for funding after peer review.

Can I submit multiple proposals?

We will consider multiple Initial Proposals from the same PI; however, we will invite at most one Full Proposal from each PI or closely associated group of applicants.

What if I am unable to submit my application electronically?

Only applications submitted through the form on our website are accepted. If you encounter problems, contact our staff at mail@fqxi.org.

Is there a maximum amount of money for which we can apply?

No. You may apply for as much money as you think is necessary to achieve your goals. However, you should carefully justify your proposed expenditure. Keep in mind that projects will be assessed on potential impact per dollar requested; an inappropriately high



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budget may harm the proposal's prospects, effectively pricing it out of the market. Referees are authorized to suggest budget adjustments.

What will an average award be?

We expect that research awards will typically be in the range of \$50,000-\$150,000 total over the life of the award (usually one to two years), with outreach awards substantially smaller.

What are the reporting requirements?

Grantees will be asked to submit annual grant renewal applications. Renewal of multi-year grants will be contingent on satisfactory demonstration in these applications that the supported research is progressing appropriately, and continues to be consistent with the spirit of the original proposal.

What are FQXi “Mini-Grants”?

FQXi has initiated an on-going program to fund small projects (approximately US\$1-\$15K) by FQXi Members only. See fqxi.org/grants/mini/intro for details.

What are the qualifications for a Principal Investigator?

Since this is a program run by researchers for researchers, FQXi may be a bit more flexible than traditional funding agencies in the definition of a Principal Investigator; thus, we may accept applications from postdoctoral fellows as the PI or a co-investigator if his/her institution allows this. Should a postdoctoral fellow be invited to submit a Full Proposal, s/he must obtain co-signatures on the proposal from the department head, as well as a department host with a post extending the duration of the grant.

My colleague(s) and I would like to apply as co-PIs. Can we do this?

Yes. For administrative purposes, however, please select a primary contact for the life of the award. The primary contact, which must be a Principal Investigator, will be the reference for your application(s) and all future correspondence, documents, etc.

Can you fund PhD student research assistantships?

Yes. However, because of the unconventional nature of the FQXi mission, full-time student support is discouraged. Potential students cannot directly apply for a studentship.

Will the grants pay for laboratory expenses?

Yes, however due to budgetary limitations FQXi cannot fund capital-intensive equipment. Also, laboratory expenses must be clearly required by the proposed research, which must clearly fulfill the ‘foundational’ relevance criterion.

I have a proposal for my usual, relatively mainstream research program that I may be able to neatly repackage as an appropriate proposal for FQXi. Sound OK?



FQXi is very sensitive to the problem of "fishing for money"—that is, the re-casting of an existing research program to make it appear to fit the overall thematic nature of this Request For Proposals. Such proposals will not be funded, nor renewed if funded initially.

APPENDIX B: EXAMPLE PROJECTS

To aid prospective applicants in determining whether a project is appropriate for FQXi, we have provided lists of questions and topics that make suitable targets for research funded under this program, as well as some borderline or unlikely topics. The lists are far from exhaustive—we are sure there are many more questions out there! The topics of previous awardees can be found online at fqxi.org/grants/large/awardees/list.

❧ **Questions on the Nature of Time:** Questions particular to the Nature of Time focus of this program include the following. (Note that proposals on these subjects are likely to be topical, but proposals also must be sufficiently **foundational** and **unconventional**.)

- Are the laws of physics time-symmetric? Are they time reversible?
- How does one explain the time symmetry of some physical laws and the asymmetry of others?
- Is the universe a static “block” universe? Is the flow of time an illusion? If so, how do we explain this “illusion”?
- Does the big bang (at least partially) explain the entropic arrow of time?
- Is the nature of time intrinsically different from that of space? Why?
- Can physical time be infinite?
- Are there many space-time branches or timelines in addition to our own?
- What do the theory of relativity and quantum mechanics (QM) respectively tell us about the nature of time and time travel? Do these theories provide us with inconsistent conceptions of time?
- If we could experimentally confirm or discard any of the key specific interpretations of QM or classes of interpretation (such as collapse accounts), would we gain insight on the problems of time?
- Can QM explain the beginning of time?
- Is space-time itself quantized? If so, what does it mean?
- Can we, by way of experiments employing different reference frames, experimentally confirm the existence of anything such as the need for preferred foliations, inconsistent histories, advanced action, evolving spacetime, etc., that argues against the block-universe interpretation of relativity theory?
- Does non-locality in QM give us good reason to modify relativity?

- Are there new QM experiments (thought or otherwise) involving weak values, pre- and post- selection, etc., that bear on the problems of time? For example, are there such experiments that are best interpreted as requiring “BCQM” or advanced action?
- Are there any specific accounts of time-symmetric quantum mechanics, such as truly new time-symmetric dynamics, that bear on the problems at hand, suggest new predictions, etc.?
- Is the Everett-Wallace-Saunders interpretation of QM truly local and consistent with “M4” and “blockworld”? If so, how does this or any other view which takes the wave function as fundamental (such as GRW) recover M4 and relativity?
- How many spatial dimensions are there? Can this question be resolved empirically or experimentally? Can there be more than one temporal dimension?
- Is the Tumulka-GRW interpretation truly covariant, and can it be extended to cases with interactions?
- Does Bohmian mechanics require a preferred frame, and if so does that undermine the Bohmian interpretation of QM or special relativity?
- How can time be recovered from the timeless Wheeler-Dewitt equation? Must we modify the equation? Or replace it altogether?

☞ **Suitable general topics:** Projects suitable for the general portion of this program are best exemplified by past winners, such as the following representative selection.

- Development of methods to compute probabilities for observables in a string theory/eternal inflation multiverse
- A novel mathematical approach to quantum gravity
- A study of possibilities for life in a universe with different fundamental constants, atomic physics, chemistry, etc.
- Invention, substantial development, or experimental testing of a non-standard formulation of quantum mechanics such as nonlinear wave-function reduction or Bohm's hidden variables
- A novel technology or experiment for SETI
- A novel technology or experiment for testing an aspect of quantum mechanics
- A workshop on an aspect of quantum gravity
- Lecture series, panel or dialogue between eminent scientists on foundational questions in physics and astronomy, intended for a lay audience

☞ **Borderline general topics:** Certain topics might be appropriate, but would require closer scrutiny of the project particulars.

- A prototype experiment for a novel method of accelerating particles to very high energies cheaply (may be appropriate if it enables qualitatively new research on foundational questions)
- An assessment of whether life could survive interplanetary or interstellar trips to create panspermia (may be too conventional)



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- A study of Goedel's incompleteness theorem and its implications for links between mind, matter, and mathematics (may be insufficiently topical)
- A study of the mathematics behind many linked oscillators, and how collective phenomena such as flocking or synchronization emerge, applied to astrophysics (perhaps not sufficiently foundational or unconventional)
- Development of a new alternative to inflation, or further developing an existing one such as variable speed-of-light or the cyclic model (may be too conventional)

✂ **Unlikely general projects:** Projects along the following lines are unlikely to receive funding.

- Research in 'mainstream' string theory or string cosmology (probably too conventional)
- Developing a novel candidate for dark matter (probably not foundational or unconventional)
- Astrophysical determinations of dark energy properties (too conventional)
- Mathematical models of evolution (not topical, and probably too conventional)
- An idea for a breakthrough energy source such as exothermic tabletop fusion (neither topical nor foundational)
- Study of the philosophy of consciousness (Applications for philosophical work are discouraged unless they connect in a relevant and analytical way with physical science.)

APPENDIX C: IMPORTANT DATES

June 14, 2010	Deadline for Initial Proposals
Early August, 2010	Invitations to submit Full Proposals offered
September 30, 2010	Deadline for Full Proposal
Early December, 2010	Award Announcement
January 1, 2011	Earliest Start Date for Grants