# Sean Patrick Robinson

## Curriculum Vitae: August 14, 2008

Department of Physics, 4-315
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139, USA

Phone: (617) 253-4842
Fax: (617) 258-8319
Email: spatrick@mit.edu
http://www.mit.edu/~spatrick/

## Personal

Date of Birth: November 18, 1977
Place of Birth: Plymouth, MA, USA
Citizenship: United States
Married: Jamie A. Robinson, May 20, 2000
Two Children: Anna, age 6; Alexander, age 3

## Education

**Massachusetts Institute of Technology** — Cambridge, MA, 1999–2005.
Ph.D. degree in Physics (Theoretical Particle Physics).
Thesis: *Two Quantum Effects in the Theory of Gravitation.*
Thesis adviser: Prof. Frank Wilczek.

**Massachusetts Institute of Technology** — Cambridge, MA, 1995–1999.
B.S. degree in Physics; Minor in Earth, Atmospheric, and Planetary Science.
Thesis: *Single Function Call Probabilistic Quantum Algorithm for Searching an Ordered List*
Thesis adviser: Prof. Edward H. Farhi.

**Marshfield Public Schools** — Marshfield, MA, 1982–1995.

## Experience

### Administration

— **Academic Administrator**, MIT Dept of Physics. Responsible for the academic program of the MIT Dept of Physics, including management of the Physics Academic Programs Office. Also, lecturer in Physics I (8.01). (2008–Present)

— **Space and Renovation Manager, MIT Green Center for Physics**, MIT Dept of Physics. Project management for Physics Department in construction of a midsized facility for physics research, education, and administration. Approximately $60M in new construction and renovation. Also, facilities management for Physics Department laboratories and offices. Some theoretical physics research. (2005–2007)

### Teaching

— **Technical Instructor**, MIT Dept of Physics. Experimental Physics I/II (8.13/8.14) and Physics I (8.01); Also, development of a training, utilization, and assessment plan for graduate student Teaching Assistants. (2007–2008)

— **Graduate Teaching Assistant**, MIT. Particle Physics of the Early Universe (8.952), Fall 2004; Experimental Physics I (8.13), Fall 1999–2004; Experimental Physics II (8.14), Spring 2000.

— **Undergraduate Teaching Assistant**, MIT. Experimental Physics I (8.13, course material preparation), Summer 1998; Observing Stars and Planets (12.401), Spring 1998; Hands-On Astronomy (12.409), January 1998.

— See also attached **Statement of Teaching Philosophy**.

### Research

— **Ph.D. Thesis**, MIT Dept of Physics, Adviser: Frank Wilczek.
*Two Quantum Effects in the Theory of Gravitation.* (June 2005)

— **Graduate Research Assistant**, MIT Center for Theoretical Physics.
Research in theoretical particle physics and gravitation under Prof. Frank Wilczek. (1999–2005)

— **S.B. Thesis**, MIT Dept of Physics. Adviser: Edward H. Farhi.

*Single Function Call Probabilistic Quantum Algorithm for Searching an Ordered List.* (June 1999)
— **Undergraduate Researcher**, MIT Center for Space Research, Space Plasma Group.
Research in solar wind physics, primarily in interplanetary shocks. Analysis of large multivariable time series data sets from various spacecraft, including Voyager 2, IMP 8, and Ulysses. Supervisors: Alan Lazarus and Karolen Paularena. (1997–1999)
— See also attached **Bibliography** and **Research Statement**.

## Professional Activities and Awards

**Infinite Mile Award,** MIT School of Science: 2006
*For Outstanding Achievement in the Department of Physics.*

**Spot Recognition Award,** MIT School of Science: 2005, 2007.

**American Physical Society,** Member,
Units: *Div of Particles & Fields, F'm on Education, F'm on Physics & Society, New England Sec.*

**American Association of Physics Teachers,** Member.

**Sigma Xi** scientific research society, Associate Member (Inactive).

**Referee/Reviewer** Physical Review Letters, Physical Review D, Physics Letters B, General Relativity and Gravitation.

## Other Activities

**Judo** Rank: nikyu (2nd degree brown belt); President MIT Judo Club 2000–2004; Assistant Instructor MIT Judo Club 2005–2006; Member US Judo Federation and USA Judo, Inc; Numerous competitive awards.

**Photography** (amateur), Exhibitions: *Sparks and Rebar*, December 2005, MIT Compton Room; *PDSI Physics Gallery*, February 2006–April 2007, MIT Physics Headquarters.

## References

Prof. Frank Wilczek
MIT Ctr. for Theoretical Physics
6-301
77 Massachusetts Avenue
Cambridge, MA 02139
617-253-0204
wilczek@mit.edu

Dean Marc Kastner
MIT School of Science
6-123
77 Massachusetts Avenue
Cambridge, MA 02139
617-253-8900
mkastner@mit.edu

Prof. Richard Yamamoto
MIT Dept. of Physics
26-421
77 Massachusetts Avenue
Cambridge, MA 02139
617-253-6073
rky@mit.edu

# Bibliography

## Publications and preprints

[1] S. Das, S. P. Robinson, and E. C. Vagenas, "Gravitational anomalies: a recipe for Hawking radiation", Int. J. Mod. Phys. D **17**, 533 (2008), [arXiv:0705.2233].
*Received Honorable Mention in the 2007 Gravity Research Foundation Essay Contest.* Status and developments of the Robinson-Wilczek anomaly method are reviewed.

[2] S. P. Robinson, "Normalization conventions for Newton's constant and the Planck scale in arbitrary spacetime dimension", [arXiv:gr-qc/0609060].
The relationship between the coupling coefficients of general relativity and it's Newtonian limit are calculated in arbitrary spacetime dimension. A dimension-dependent factor which is often neglected in the literature is elucidated.

[3] S. P. Robinson and F. Wilczek, "Gravitational Correction to Running of Gauge Couplings", Phys.Rev.Lett **96** 231601 (2006), [arXiv:hep-th/0509050].
One-loop graviton corrections to the running of gauge couplings are calculated. Gravity appears to render all gauge couplings asymptotically free.

[4] S. P. Robinson and F. Wilczek, "Relationship Between Hawking Radiation and Gravitational Anomalies", Phys.Rev.Lett. **95**, 011303 (2005), [arXiv:gr-qc/0502074].
Hawking radiation is shown to be a requirement for maintaining general covariance in the effective quantum theory of fields living around a black hole.

## Theses

[5] Sean Patrick Robinson, "Two Quantum Effects in the Theory of Gravitation", MIT Ph.D. Thesis in Physics, June 2005.
Two small steps from classical to quantum gravity are explored: quantum field theory in curved spacetime and quantum general relativity as an effective field theory. Within the former, the effective theory of fields near a black hole is studied, while in the latter the effects of quantum gravity on the renormalization of Yang-Mills couplings are calculated.

[6] Sean Patrick Robinson, "Single Function Call Probabilistic Quantum Algorithm for Searching an Ordered List", MIT S.B. Thesis in Physics, June 1999.
A procedure is described for finding a marked item on a sorted list of $N$ items using a quantum computer. The procedure succeeds with probability scaling as $\ln(N)/N$ after a single query to the list. The best classical procedure yields only $2/N$.

## Manuscripts in preliminary preparation

[7] S. P. Robinson, "Notes on arbitrary dimensional black holes".
Some useful results on the most general static, spherically symmetric solutions to Einstein's equations in arbitrary spacetime dimension are collected. Conditions for the existence of event horizons are discussed. Familiar calculations from the four-dimensional Schwarzschild solution, such as the construction of extended Kruskal coordinates and Unruh's derivation of the Hawking effect, are generalized to the arbitrary case.

[8] S. P. Robinson, "Notes on the wave equation in arbitrary spherically symmetric static spacetimes".
Some useful results on the solutions of the scalar wave equation in general static, spherically symmetric spacetimes of arbitrary dimension are collected. The generalized spherical harmonics are solved for exactly. The radial equation is solved for a few special cases. Special attention is paid to properties of solutions in the vicinity of an event horizon, where we find that, in general, physics becomes essentially two-dimensional.

[9] S. P. Robinson, "Blackbody radiation in arbitrary dimension and in spherical coordinates".
Textbook calculations for the spectral and bulk properties of blackbody radiation are generalized for

arbitrary spacetime dimension. The calculation is also carried out in spherical coordinates such that the partial wave mode thermal occupation spectrum is derived.

[10] S. P. Robinson, “Pedagogical Quantum Insert”.
The procedure of [6] for finding a marked location on a sorted list with greater-than-classical probability after a single quantum query is presented in such a way as to make clear where the quantum improvement originates.

## Talks and Presentations

**2005** “Two Quantum Effects in the Theory of Gravitation”, Thesis Defense, MIT.

**2005** “One-loop graviton corrections to QCD Beta Functions”, Friday Lunch Club, Center for Theoretical Physics, MIT.

**2003** “Hawking Radiation and Gravitational Anomalies”, Friday Lunch Club, Center for Theoretical Physics, MIT.

**2002** “Domain Wall Fermions”, Friday Lunch Club, Center for Theoretical Physics, MIT.

# Statement of Research Interests

My primary research interests lie in quantum field theory, general relativity, and the various points of connection between these two formalisms. The ultimate motivation for study in this field is to discover pieces of the path from known physics toward some eventual future theory of quantum gravity. In the process, many phenomena from other fields of physics are encountered which are interesting in their own right. These include black holes (astrophysics), coupling constant flow (traditional particle physics), and anomaly driven currents (condensed matter and relativistic quantum field theories). In a certain sense, the combination of gravitation and quantum field theory is an example of a quantum system in the presence of a nontrivial background. Thus, these studies are not too distant from Casimir effects, quantum fluid mechanics, and theories of brane-string interactions.

One direction in which I've pursued these ideas is a calculational method developed by myself and Frank Wilczek [1, 2]. We attempted to formulate an effective theory for a scalar field in a fixed black hole background spacetime. We found that the effective theory contains a gravitational anomaly — a conflict between conservation laws and quantum mechanics that renders the theory meaningless — which is removed by a flux of radiation from the black hole horizon at a specified temperature (Hawking radiation).

Loosely speaking, an effective theory is a description of a system in terms of the physical modes that are accessible to a given observer; the other modes are "integrated out". For an observer outside a black hole, this means field modes inside the black hole must be integrated out. This observer also sees outgoing particle states whose energy density diverges very near to the horizon. These "horizon skimming" modes must also be integrated out of the effective theory. The effective field theory thus formed is chiral at the horizon, because it lacks modes propagating out of the horizon but still allows modes that fall through. However, such a chiral theory contains a quantum anomaly in general covariance (local conservation of energy-momentum) that is localized at the horizon, indicating that the theory breaks down there. The full theory is generally covariant, however, so some mechanism must exist to restore general covariance in the effective theory.

Our main result is that general covariance can indeed be restored in the effective theory by a special choice of boundary condition which demands that each partial wave mode of the scalar field must be occupied such that it carries an energy-momentum flux equal in magnitude to that of thermal radiation at the Hawking temperature. The result holds in any spacetime dimension and with any scalar self-interaction potential.

We studied the case of static, spherically symmetric black holes. The result has been taken up and generalized by several authors. Iso, et. al. [3] studied the case of a charged black hole coupled to a gauge field. They found that the effective theory exhibited both gravitational and gauge anomalies. Canceling both anomalies produced not just Hawking radiation, but also the expected super-radiant charged current. Then, [4] and [5] independently considered the case of four-dimensional Kerr-Newman (charged, rotating) black holes and found that in the effective chiral theory, the rotation acts like an additional Abelian gauge charge, at which point the results of [3] can be applied to find the correct angular-momentum dependent Hawking flux. Since that time, the method has been extended and applied to many special cases by scores of authors. A review of the subject is given in [2]. Successful extensions of the method include time dependent horizons, cosmological horizons, and black rings. Recent work by Iso, et. al. [6] strongly suggests that the method can be used to calculate the full thermal spectrum of Hawking radiation, instead of just the net fluxes.

More open questions remain in this study. Does it tells us anything about black hole entropy? What does this method imply about the nature of effective field theory in curved spacetimes and other backgrounds? Also, while the mechanism provides us with a way of formulating effective field theory over a well-behaved patch of curved spacetime, it hasn't shown us how to connect adjacent patches. This question of how to formulate effective field theories in curved spacetimes, and its possible connection to anomaly inflow mechanisms in effective field theories, is an interesting question to pursue. This method is remarkably similar to other anomaly inflow mechanisms, such as those in quantum Hall systems and in exotically charged solitons, but how does this relationship work in detail? These questions are all amenable to future study.

This research has raised my interest for several related subjects. Within field theory, one example is Casimir effects. (What are the Casimir corrections to thermodynamics? What is the nature of radiations from dynamical Casimir systems, and are they useful for anything? Can Casimir forces be understood as anomaly inflows?) This is related to another example, namely the study of classical energy conditions in quantum field theories. (For how general a field theory can one prove the quantum interest conjecture? What do the quantum conditions imply for exotic solutions of general relativity, i.e. does nature abhor a time machine?) Another example is the asymptotic safety scenario for gravity. (What is the conformal field theory at the proposed fixed point? What are the implications of it's existence? How do we calculate with such theories in general?) I am also interested in phenomenological issues falling under the general heading of "beyond the Standard Model".

This is an interesting time in a several of fields of physics outside of particle theory, as well. Some are at transitional stages, like gravitational wave astronomy. Some are emerging in a formative stage, like topological quantum computing. Some are approaching a new "golden age" of experimental data, like cosmology and high energy experiment. Some are potentially on the verge of a merger, like condensed matter and atomic physics, via BEC-BCS crossover physics. These are good opportunities for an outsider to transition into a new field, bringing in new skills to apply to new problems. I would be excited to participate in projects in any of these fields, and would especially welcome the experience of experimental work.

[1] S. P. Robinson and F. Wilczek, Phys.Rev.Lett. **95**, 011303 (2005), [arXiv:gr-qc/0502074].

[2] S. Das, S. P. Robinson, and E. C. Vagenas, Int. J. Mod. Phys. D **17**, 533 (2008), [arXiv:0705.2233].

[3] S. Iso, H. Umetsu and F. Wilczek, Phys. Rev. Lett. **96**, 151302 (2006) [arXiv:hep-th/0602146].

[4] S. Iso, H. Umetsu and F. Wilczek, Phys. Rev. D **74**, 044017 (2006) [arXiv:hep-th/0606018].

[5] K. Murata and J. Soda, Phys. Rev. D **74**, 044018 (2006) [arXiv:hep-th/0606069].

[6] S. Iso, T. Morita and H. Umetsu, [arXiv:0710.0456].

# Statement of Teaching Philosophy

My approach to the classroom is rather simple: understand the audience, know the material, and stay focussed on the point. This is similar to my approach for other forms of technical communication — such as a research seminar or a written article — simply scaled up in size. However, there are a few aspects that distinguish teaching from other communications. Cultural and social diversity play a stronger role in the classroom, as do the diversity of the students' motivations and incoming preparation for the subject. The teacher who does not account for these aspects of his audience is destined for difficulty. Also, the goal of a course may be more complex than simply delivering a certain body of knowledge to the audience. Whether the course is intended primarily for non-majors, or as a stepping stone into independent study for advanced students, or somewhere in between, the teacher again needs to account for this in his delivery.

There is at least one element I feel could be a larger part of any technical class, especially a physics class. The necessity of being able to communicate one's scientific results should be emphasized constantly. Technical writing and presentation are skills which require practice. Short written and oral reports on subjects related to the material are often a better teaching tool than periodic quizzes. For upperclass students, these could be formalized in the style of Physical Review Letters or twelve-minute APS talks. Communication-centered teaching naturally lends itself to research skills like literature searching and ultimately to original research itself. Young scientists today are increasingly expected to prepare their own graphics and manuscripts, including proper typesetting. While there are many software tools on the market for this, LaTeX-based systems are now widely used in science, engineering, and mathematics. They can also easily been taught within the framework of a class that already has a technical writing focus. Communication-centered teaching provides a skill that is useful for any student in the class, no matter their major. Unlike a writ problem set which instructs the student to answer the professor's question, a communication assignment allows the student to engage both the problem and the audience from their own point of view: whether the student has a focus in environmental science, or history, or public policy, the assignment allows the freedom to slant any topic toward the direction of choice.

Most of my classroom teaching experience has been in an upper level experimental physics laboratory class (M.I.T. 8.13, "Junior Lab") where students were required to perform, analyze, and report on five experiments in modern physics in the course of a semester (roughly once every two weeks). Reporting was in the short form described above, both oral and written, for an audience of a few people. Further, the students would choose one experiment to focus on for a polished final presentation in front of all their classmates and faculty at the close of the semester. While the focus of the course was on the content of experimental physics, students received ample coaching on their writing and speaking technique. In the course of the semester, even the weakest students would gain enough practice at technical communication to give a presentation before an audience of a couple dozen people that would rival the quality of a session talk at an academic conference.

My other primary teaching experience is lecturing introductory mechanics (M.I.T. 8.01, Physics I), a required course for all first-year students. Nearly 90% of students in this class have no intention of majoring in physics. They take the course only because it is a requirement for graduation. Moreover, while some of these students have taken AP physics and calculus in high school, others have had only algebra and no physics. Communicating with and motivating this audience is challenging. This class is taught in a studio format that blends lecturing, group problem solving, experiments, and demonstrations. It also features heavy use of technology in the classroom, ranging from projection screens and video capture of white boards, to the use of electronic polling devices to get active real time feedback on students' understanding of concept questions. These same teaching methods could be incorporated into a variety of courses.

There are variety of physics subjects I would like the opportunity to teach in the future. Teaching standard core courses is always rewarding, but so would be teaching a broad survey course directed at non-majors. I would also enjoy teaching a course in cosmology and particle physics. The beauty of this subject is that it can be presented at a great variety of levels, wherever the greatest student demand is. Plus, we are quickly coming to an age where cosmology and particle physics could be taught as a "current events" course on experimental results. I would also like to teach special topics courses close to my own research in order to engage students in research activities. Contrary to popular belief, general relativity can be taught effectively at the advanced undergraduate level. Also, I was recently able sit as a listener in a single semester course where string theory was successfully taught to undergraduates. I would very much like to attempt repeating that feat. If string theory and general relativity can be taught to undergraduates, then certainly quantum field theory can be, as well. Although I have never seen that done, I would like to give it a try.