

Sean M. Carroll

Johns Hopkins University

*Bloomberg Center for Physics and Astronomy
3400 N. Charles St.
Baltimore, MD 21218, USA
✉ seancarroll@gmail.com
🌐 www.preposterousuniverse.com*

Current Positions

- 2022- **Johns Hopkins University**
Homewood Professor of Natural Philosophy
- 2019- **Santa Fe Institute**
Fractal Faculty (External Professor, 2019-2021)

Research Interests

Theoretical physics. Quantum spacetime, cosmology, field theory, gravitation, emergence, complex systems.

Philosophy. Foundations of quantum mechanics and statistical mechanics, philosophy of cosmology, emergence, causation, naturalism.

Education

- 1984-1988 **Villanova University**
B.S. Astronomy and Astrophysics, B.A. Honors Program
Magna Cum Laude; Minors in Physics, Philosophy
- 1988-1993 **Harvard University**
Ph.D. Astronomy (George Field, advisor)
Thesis: *Cosmological Consequences of Topological and Geometric Phenomena in Field Theories*

Previous Positions

- 1993-1996 **Massachusetts Institute of Technology**
Postdoctoral Researcher, Center for Theoretical Physics, and Lecturer, Physics
- 1996-1999 **Institute for Theoretical Physics, UC Santa Barbara**
Postdoctoral Researcher
- 1999-2006 **University of Chicago**
Assistant Professor, Physics and Enrico Fermi Institute
- 2006-2022 **California Institute of Technology**
Research Professor of Physics

Research Highlights

Spacetime Symmetries I pioneered the study of Lorentz violation through low-energy effective Lagrangians, including proposed observational tests [1, 18]. I also proposed some of the first experimental limits on non-commutative modifications of electromagnetism [29], and constraints on dynamical Lorentz-violating fields [35, 45, 52, 53]. I have developed frameworks in which to analyze possible large-scale deviations from cosmological isotropy [44, 46, 48, 50]. Closer to home, I pointed out that average energy is not conserved in quantum measurements, and proposed an experimental test [98].

Dark Matter, Dark Energy, Dark Forces I proposed experimental constraints on dynamical dark energy through its coupling to other fields, as well as suggesting how to avoid those constraints by imposing symmetries [22]. The best-motivated models of dark energy predict cosmological birefringence at a potentially observable level, which is currently being searched for observationally. I also pioneered theories of dark matter coupled to long-range forces [19, 47, 55, 61], including the possibility of an unbroken analogue of electromagnetism in the dark sector [49].

Modified Gravity Understanding the acceleration of the universe, usually attributed to dark energy, is one of the major challenges in theoretical physics today. Since our evidence for dark energy is exclusively through its gravitational effects, I suggested that a simple modification of Einstein's equation, known as $f(R)$ gravity, could cause acceleration without dark energy [34, 37, 43]. This idea now serves as a popular testing ground for cosmological deviations from general relativity. I explored modifications of GR due to extra dimensions [28, 33, 41] and proposed observational tests [23, 30].

Origin of the Universe & the Arrow of Time One major clue to the origin of the universe is the low entropy of the early state, responsible for the arrow of time. I proposed the first time-symmetric model of a multiverse in which the thermodynamic arrow of time arises naturally [38,39]. I have developed measures of cosmological fine-tuning [59, 63, 67, 70], and studied the possibility of the universe fluctuating into a proto-inflationary state [60]. I showed for the first time how cosmic evolution could spontaneously compactify dimensions of spacetime [56].

Foundations of Quantum Mechanics In the Everett or Many-Worlds formulation of quantum mechanics, the Born rule, that probabilities are given by the amplitude squared, must be derived rather than postulated. I proposed a new solution to this problem based on the notion of self-locating uncertainty [65, 69]. Applying the Everett formulation to cosmology and gravitation, I argued that it is possible to sidestep the Boltzmann Brain problem if Hilbert space is infinite-dimensional [66], and that black hole firewalls can be avoided if there are a sufficient number of branches of the wave function [86].

Emergent Spacetime The most minimal approach to quantum theory is one where both spacetime and fields are emergent from the kinematics and dynamics of a state vector in Hilbert Space evolving under a given Hamiltonian, an approach we dubbed "Mad-Dog Everettianism" [88]. The geometry of space can be defined by the entanglement of Hilbert-space factors [76], and Einstein's equation for gravity emerges from a requirement of entanglement equilibrium [85]. I also proposed an algorithm for decomposing Hilbert space into subsystems [97].

Statistical Mechanics and Complexity I have argued that, while entropy increases in closed systems, natural measures of "complexity" first increase and then decrease [68]. I have proposed a new Bayesian formulation of the Second Law of Thermodynamics, which incorporates the outcomes of measurements into a tighter inequality obeyed by the evolution of open systems [74].

Honors and Awards

- Named Lectures Malmstrom Lecturer, Hamline University, 2003; Resnick Lecturer, Rensselaer Polytechnic Institute, 2003; National Science Foundation NSF Distinguished Lecturer, 2007; Kieval Lecturer, Cornell University, 2011; Brattain Lecturer, Whitman College, 2014; Keynote Address, American Humanist Association, 2014; Schrödinger Colloquium, Universität Zürich, 2014; Gifford Lectures in Natural Theology, Glasgow, 2016; Beyond Annual Lecture, Arizona State University, 2017; Patrick Suppes Lecture in Logic or Philosophy of Science, Columbia University, 2019
- 1984-1988 Villanova University Presidential Scholar
- 1988 Phi Beta Kappa
- 1988 Villanova University Academic Medallion: Bachelor of Science, Astronomy and Astrophysics; Bachelor of Arts, Honors Program
- 1988-1991 National Science Foundation Graduate Fellowship
- 1991-1993 National Aeronautics and Space Administration Graduate Fellowship
- 1996 MIT Graduate Student Council Teaching Award
- 1997 American Physical Society Congressional Fellowship (declined)
- 2000-2002 Alfred P. Sloan Foundation Fellowship
- 2000-2005 David and Lucile Packard Foundation Fellowship for Science and Engineering
- 2005 Second Place (with Jennifer Chen), Gravitational Research Foundation Essay Competition
- 2006 Villanova University College of Liberal Arts and Sciences Alumni Medallion
- 2006 Spherical Cow Award for Graduate Physics Teaching, University of Chicago
- 2009 Second Prize, Foundational Questions Institute Essay Competition
- 2010 Fellow, American Physical Society
- 2010 *From Eternity to Here*: Best books of 2010, *Wilson Quarterly*
- 2013 *The Particle at the End of the Universe*: Best books of the year, *Financial Times*, *The Guardian*, *New Scientist*, Phi Beta Kappa, *Physics World*, *The Times* (UK)
- 2013 Royal Society Winton Prize for Science Books
- 2013-15 100 Global Thought Leaders, Gottlieb Duttweiler Institute
- 2014 Emperor Has No Clothes Award, Freedom From Religion Foundation
- 2014 Andrew Gemant Award, American Institute of Physics
- 2015 Fellowship, John Simon Guggenheim Foundation
- 2016 *The Big Picture*: *New York Times* bestseller list, *AudioFile* Earphones Award, Best books of the year: Amazon.com, Goodreads, *Kirkus*, *Science Friday*, *Financial Times*, *Forbes*
- 2018 Third Prize, Foundational Questions Institute Essay Competition
- 2019 *Something Deeply Hidden*: *New York Times* bestseller list, Best books of the year: Amazon.com, Goodreads, *Sunday Times*, *Science News*, *BBC Science Focus*, *symmetry*
- 2020 Fellow, American Association for the Advancement of Science
- 2022 *The Biggest Ideas in the Universe*: *New York Times* bestseller list, Best books of the year, Amazon.com

Activities

- Professional Societies American Physical Society, American Association for the Advancement of Science, Philosophy of Science Association, Authors Guild, Foundational Questions Institute
- 2002 JPL Advisory Committee on Gravitation and Fundamental Physics
- 2001-2002 Roadmap Team Member, NASA Structure and Evolution of the Universe Theme
- 2001-2005 Theory MRC Leader, Kavli Institute for Cosmological Physics
- 2004-2007 Executive Committee, APS Topical Group on Gravitation
- 2005-2012 Co-founder and contributor, *Cosmic Variance* blog
- 2007-2009 APS Committee on Informing the Public
- 2010-2012 Contributing Editor, *Discover* Magazine
- 2011 Juror, Alfred P. Sloan Prize, Sundance Film Festival
- 2012-2013 "Discoverers" consultant, Discovery Communications
- 2012 Judge, 3 Quarks Daily Science Blogging Prize
- 2013-present Board of Advisors, *Nautilus* magazine
- 2013 JPL Futures Strategy Committee
- 2014-2016 Judge, Buchalter Cosmology Prize
- 2014-2016 Advisory Panel, The Science Channel
- 2016-2019 Member, California Quantum Interpretation Network
- 2016-present Editorial Board Member, *Foundations of Physics*
- 2018-present Host, *Mindscape* podcast
- 2018-present Charter Honorary Fellow, John Bell Institute for the Foundations of Physics
- 2019-2021 Advisory Board Member, Santa Fe Institute Program on Complex Time
- 2019-present Editorial Board Member, *Physical Review Research*
- 2019-2022 Gemant Award Committee, American Institute of Physics
- 2020-present Selection Committee and Educational Advisory Board, Guggenheim Foundation
- 2021-present Scientific Advisory Panel Member, Foundational Questions Institute
- 2021-present Editorial Board Member, *Philosophy of Physics*
- 2022-present Faculty Affiliate, SNF Agora Institute, Johns Hopkins
- 2022-present Co-Founder and Co-Director, Natural Philosophy Forum, Johns Hopkins

Organizing

- 1997 Organizer, 13th Pacific Coast Gravity Meeting, Santa Barbara
- 1999 Session Organizer, Cosmic Genesis and Fundamental Physics, Sonoma
- 2001 Scientific Organizing Committee, GR16, Durban, South Africa
- 2001 Working Group Co-Convenor (Astro/Cosmo/Particle Physics), Snowmass 2001: The Future of Particle Physics.
- 2001 Organizer, EFI Mini-Symposium: String Theory and Experiment, University of Chicago
- 2001 Local Organizing Committee, Workshop on Cosmological Probes of Dark Energy, Chicago

(organizing cont.)

- 2002 Co-Chair, Local Organizing Committee, Cosmo-02 International Workshop on Particle Physics and the Early Universe, Chicago
- 2003 Co-Director, Short Course on Origin of Structure in the Universe, Center for Cosmological Physics, Chicago
- 2003 Program Co-Organizer, Kavli ITP Program on Superstring Cosmology, Santa Barbara
- 2004 Program Committee, Moriond Conference on Exploring the Universe, La Thuile, Italy
- 2004 Scientific Organizing Committee, GR17, Dublin, Ireland
- 2005 Organizer, AAAS Symposium on Understanding Dark Energy, Washington, D.C.
- 2005 Organizer, APS April Meeting Symposium on Cosmological Constraints on Gravitation and Fundamental Physics, Tampa
- 2005 Organizing Committee, Symposium on *Why So Few Women in Science?*, University of Chicago
- 2010 Organizer, AAAS Symposium on The Arrow of Time, San Diego
- 2011 Organizing Committee, Challenges for Early Universe Cosmology, Perimeter Institute
- 2011 Organizing Committee, Foundational Questions Institute Conference, *Setting Time Aright*, Bergen/Copenhagen
- 2012 Organizer, Moving Naturalism Forward workshop, Stockbridge, MA
- 2014 Organizing Committee, Primordial Gravitational Waves & Cosmology Workshop, Caltech
- 2016 Organizing Committee, Reconciling Tests of Gravity Workshop, Caltech
- 2018 Organizing Committee, Time in Adaptive Systems Workshop, Santa Fe Institute

Courses Taught

Harvard University

- 1989 Astronomy 300, General Relativity Seminar (graduate)

Massachusetts Institute of Technology

- 1996 Physics 8.962, General Relativity (graduate)

University of Chicago

- 2002, 2004, 2005 Physics 264, Spacetime and Black Holes (undergraduate)
- 2002, 2004 Physics 300, The Teaching and Learning of Physics (graduate)
- 2000, 2001 Physics 363, Particle Physics (graduate)
- 2001, 2003, 2005 Physics 364, General Relativity (graduate)
- 2001, 2006 Physics 371, Introduction to Cosmology (graduate)
- 2004 Big Problems 246, Moments in Atheism (undergraduate)

California Institute of Technology

- 2017 Physics 125c, Quantum Mechanics (undergraduate)

Johns Hopkins University

- 2022 First-Year seminar 001.142, The Physics of Democracy (undergraduate)
- 2022 Philosophy 150.464, Topics in the Philosophy of Physics (undergraduate)

Advising

Summer undergrad research students	Teodora Beloreshka (Caltech, 2000), Augusta Abrahamse (American University, 2002), Suz Tolwinski (Brown, 2004), Nicholas Scianmarello (Caltech, 2010), Aliza Malz (Caltech, 2010)
Undergrad Thesis Students	Ethan Honda (MIT, 1996), Monica Guica (Chicago, 2003), Stefan Mendez-Diez (Chicago, 2004), Abhishek Kumar (Chicago, 2004), Kevin Kuns (Caltech, 2012), Mengshuen Chua (Caltech [philosophy], 2015), Jackie Lodman (Caltech, 2020)
Ph.D. Students Supervised	Mark Hoffman (Chicago, 2003), Eugene Lim (Chicago, 2004), Jennifer Chen (Chicago, 2005), Ignacy Sawicky (Chicago, 2007), Lotty Ackerman (Caltech, 2009), Heywood Tam (Caltech, 2010), Chien-Yao Tseng (Caltech, 2013), Kimberly Boddy (Caltech, 2014), Jason Pollack (Caltech, 2017), Grant Remmen (Caltech, 2017), Aidan Chatwin-Davies (Caltech, 2018), ChunJun Cao (Caltech, 2018), Ashmeet Singh (Caltech, 2020)
Ph.D. Students co-supervised or closely worked with	Simeon Hellerman (UCSB, 2001), Laura Mersini (Wisconsin-Milwaukee, 2000), Takemi Okamoto (Chicago, 2004), James Geddes (Chicago, 2005), Vikram Duvvuri (Chicago, 2007), Jing Shu (Chicago, 2008), Adrienne Erickcek (Caltech, 2009), Moira Gresham (Caltech, 2010), Timothy Dulaney (Caltech, 2011), Charles Sebens (Michigan, 2015), Anthony Bartolotta (Caltech, 2018)
Postdocs Supervised	Manoj Kaplinghat (Chicago, 1999-2002), Cristian Armendariz-Picon (Chicago, 2001-2004), Geraldine Servant (Chicago/Argonne, 2001-2004), Matthew Johnson (Caltech, 2007-2010), Ingunn Wehus (Caltech, 2007-2010), Matthew Buckley (Caltech, 2008-2010), Stefan Leichenauer (Caltech, 2011-2014), Ning Bao (Caltech, 2014-2017)

Film/Television Consulting (with main contacts)

2007	<i>Angels and Demons</i> (Ron Howard, director; Brian Grazer, producer)
2008, 2013	<i>Bones</i> (Janet Lin, writer; Emily Silver, writer)
2009	<i>TRON: Legacy</i> (Jeffrey Silver, producer; Joseph Kosinski, director)
2009	<i>Thor</i> (Kevin Feige, producer; Kenneth Branagh, director; Don Payne, writer)
2011	<i>Fringe</i> (Glen Whitman, writer)
2013	<i>Thor: The Dark World</i> (Kevin Feige, producer; Alan Taylor, director)
2014	<i>Big Hero Six</i> (Don Hall, director)
2015	<i>Terminator: Genysis</i> (Alan Taylor, director)
2016	<i>Spectral</i> (George Nolfi, writer)
2017	<i>Downsizing</i> (Alexander Payne, director)
2018	<i>Inversion</i> (Samuel Nozick, co-producer)
2019	<i>Avengers: Endgame</i> (Russo Brothers, writers/directors)
2021	<i>Halo</i> (Steven Kane, executive producer)

Research Publications

1. S.M. Carroll, G.B. Field and R. Jackiw, 1990, "Limits on A Lorentz and Parity-Violating Modification of Electrodynamics," *Phys. Rev. D* **41**, 1231.
2. E.F. Guinan and S.M. Carroll, 1990, "Eclipsing Binaries as Astrophysical Laboratories and the Strange Case of Epsilon Aurigae," in *Active Close Binaries: NATO ASI meeting at Kudasi, Turkey*, ed. C. Ibanoglu and I. Yavuz (Kluwer: Dordrecht), 7.
3. S.M. Carroll, E.F. Guinan, G.P. McCook and R.A. Donahue, 1991, "Interpreting Epsilon Aurigae," *Astrophys. J.* **367**, 278.
4. S.M. Carroll and G.B. Field, 1991, "The Einstein Equivalence Principle and the Polarization of Radio Galaxies," *Phys. Rev. D* **43**, 3789.
5. S.M. Carroll, E. Farhi and A.H. Guth, 1992, "An Obstacle to Building a Time Machine," *Phys. Rev. Lett.* **68**, 263; Erratum: **68**, 3368.
6. W.D. Garretson, G.B. Field and S.M. Carroll, 1992, "Primordial Magnetic Fields from Pseudo-Goldstone Bosons," *Phys. Rev. D* **46**, 5346; [hep-ph/9209238](#).
7. J.A. Bryan, S.M. Carroll and T. Pyne, 1994, "A Texture Bestiary," *Phys. Rev. D* **50**, 2806; [hep-ph/9312254](#).
8. S.M. Carroll, D.Z. Freedman, M.E. Ortiz, and D.N. Page, 1994, "Physical States in Canonically Quantized Supergravity," *Nucl. Phys.* **B423**, 661; [hep-th/9401155](#).
9. S.M. Carroll and G.B. Field, 1994, "Consequences of Propagating Torsion in Connection Dynamic Theories of Gravity," *Phys. Rev. D* **50**, 3867; [gr-qc/9403058](#).
10. S.M. Carroll, E. Farhi, A.H. Guth and K.D. Olum, 1994, "Energy-Momentum Restrictions on the Creation of Gott Time Machines," *Phys. Rev. D* **50**, 6190; [gr-qc/9404065](#).
11. S.M. Carroll, D.Z. Freedman, M.E. Ortiz and D.N. Page, 1995, "Bosonic Physical States in $N = 1$ Supergravity?," in *Proceedings of the 7th Marcel Grossmann Meeting*, ed. R. Ruffini and M. Keiser (World Scientific); [gr-qc/9410005](#).
12. S.L. Baliunas *et al.* [27 authors], 1995, "Chromospheric Variations in Main-Sequence Stars. II," *Astrophys. J.* **438**, 269.
13. S.M. Carroll, M.E. Ortiz and W. Taylor IV, 1996, "A Geometric Approach to Free Variable Loop Equations in Discretized Theories of 2D Gravity," *Nucl. Phys.* **B468**, 383; [hep-th/9510199](#).
14. S.M. Carroll, M.E. Ortiz and W. Taylor IV, 1996, "Spin/Disorder Correlations and Duality in the $c = 1/2$ String," *Nucl. Phys.* **B468**, 420; [hep-th/9510208](#).
15. T. Pyne and S.M. Carroll, 1996, "Higher-Order Gravitational Perturbations of the Cosmic Microwave Background," *Phys. Rev. D* **53**, 2920; [astro-ph/9510041](#).
16. S.M. Carroll, M.E. Ortiz and W. Taylor IV, 1996, "The Ising Model with a Boundary Magnetic Field on a Random Surface," *Phys. Rev. Lett.* **77**, 3947; [hep-th/9605169](#).
17. A. Sornborger, S.M. Carroll and T. Pyne, 1997, "The Collapse of Exotic Textures," *Phys. Rev. D* **55**, 6454; [hep-ph/9701351](#).
18. S.M. Carroll and G.B. Field, 1997, "Is There Evidence for Cosmic Anisotropy in the Polarization of Distant Radio Sources?," *Phys. Rev. Lett.* **79**, 2394; [astro-ph/9704263](#).

(research publications cont.)

19. G.W. Anderson and S.M. Carroll, 1997, "Dark Matter with Time-Dependent Mass," in *Cosmo-97, International Workshop on Particle Physics and the Early Universe*, ed. L. Roszkowski (World Scientific: Singapore), p. 227; [astro-ph/9711288](#).
20. S.M. Carroll, M.E. Ortiz and W. Taylor IV, 1998, "Boundary Fields and Renormalization Group Flow in the Two-Matrix Model," *Phys. Rev. D* **58**, 046006; [hep-th/9711008](#).
21. S.M. Carroll and M. Trodden, 1998, "Dirichlet Topological Defects," *Phys. Rev. D* **57**, 5189; [hep-th/9711099](#).
22. S.M. Carroll, 1998, "Quintessence and the Rest of the World," *Phys. Rev. Lett.* **81**, 3067; [astro-ph/9806099](#).
23. P.M. Garnavich *et al.* [21 authors], 1998, "Supernova Limits on the Cosmic Equation of State," *Astrophys. J.* **509**, 74; [astro-ph/9806396](#).
24. S.M. Carroll and G.B. Field, 1998, "Primordial Magnetic Fields that Last?," in *33rd Rencontres de Moriond: Fundamental Parameters in Cosmology*, 17-24 January 1998, Les Arcs, France; [astro-ph/9807159](#).
25. G.B. Field and S.M. Carroll, 2000, "Cosmological Magnetic Fields from Primordial Helicity," *Phys. Rev. D* **62**, 103008; [astro-ph/9811206](#).
26. S.M. Carroll, S. Hellerman, and M. Trodden, 2000, "Domain Wall Junctions are 1/4-BPS States," *Phys. Rev. D* **61**, 65001; [hep-th/9905217](#).
27. S.M. Carroll, S. Hellerman, and M. Trodden, 2000, "BPS Domain Wall Junctions in Infinitely Large Extra Dimensions," *Phys. Rev. D* **62**, 044049; [hep-th/9911083](#).
28. S.M. Carroll and L. Mersini, 2001, "Can We Live in a Self-Tuning Universe?," *Phys. Rev. D* **64**, 124008; [hep-th/0105007](#).
29. S.M. Carroll, J.A. Harvey, V.A. Kostelecký, C.D. Lane, and T. Okamoto, 2001, "Noncommutative Field Theory and Lorentz Violation," *Phys. Rev. Lett.* **87**, 141601; [hep-th/0105082](#).
30. S.M. Carroll and M. Kaplinghat, 2001, "Testing the Friedmann Equation: The Expansion of the Universe During Big-Bang Nucleosynthesis," *Phys. Rev. D* **65**, 063507; [astro-ph/0108002](#).
31. S.M. Carroll, J. Geddes, M.B. Hoffman, and R.M. Wald, 2002, "Classical Stabilization of Homogeneous Extra Dimensions," *Phys. Rev. D* **66**, 024036; [hep-th/0110149](#).
32. S.M. Carroll, 2002, "What Do We Really Know about the Expansion of the Universe?," in *Proceedings of the Second Meeting on CPT and Lorentz Symmetry*, ed. V.A. Kostelecký (World Scientific: Singapore), p. 80.
33. S.M. Carroll, M.B. Hoffman, and M. Trodden, 2003, "Can the dark energy equation-of-state parameter w be less than -1 ?," *Phys. Rev. D* **68**, 023509; [astro-ph/0301273](#).
34. S.M. Carroll and M.M. Guica, 2003, "Sidestepping the Cosmological Constant with Football-Shaped Extra Dimensions", [hep-th/0302067](#).
35. S.M. Carroll, V. Duvvuri, M. Trodden and M.S. Turner, 2004, "Is Cosmic Speed-Up Due to New Gravitational Physics?," *Phys. Rev. D* **70**, 043528; [astro-ph/0306438](#).
36. S.M. Carroll and E.A. Lim, 2004, "Lorentz-Violating Vector Fields Slow the Universe Down," *Phys. Rev. D* **70**, 123525; [hep-th/0407149](#).

(research publications cont.)

37. S.M. Carroll, A. De Felice, and M. Trodden, 2005, "Can we be tricked into thinking that w is less than -1 ?", *Phys. Rev. D* **71**, 023525; [astro-ph/0408081](#).
38. S.M. Carroll, A. De Felice, V. Duvvuri, D.A. Easson, M. Trodden, and M.S. Turner, 2004, "The Cosmology of Generalized Modified Gravity Models", *Phys. Rev. D* **71**, 063513; [astro-ph/0410031](#).
39. S.M. Carroll and J. Chen, 2004, "Spontaneous Inflation and the Origin of the Arrow of Time", [hep-th/0410270](#).
40. S.M. Carroll, 2005, "Why (Almost All) Cosmologists Are Atheists", *Faith and Philosophy* **22**, p. 622.
41. S.M. Carroll and J. Chen, 2005, "Does inflation provide natural initial conditions for the universe?," *Gen. Rel. Grav.* **37**, 1671; [gr-qc/0505037](#).
42. S.M. Carroll and J. Shu, 2005, "Models of Baryogenesis via Spontaneous Lorentz Violation," *Phys. Rev. D* **73**, 103515; [hep-ph/0510081](#).
43. I. Sawicki and S.M. Carroll, 2005, "Cosmological Structure Evolution and CMB Anisotropies in DGP Braneworlds," [astro-ph/0510364](#).
44. S.M. Carroll, 2006, "Is our universe natural?," *Nature*, 440, 1132; [hep-th/0512148](#).
45. S.M. Carroll, I. Sawicki, A. Silvestri, and M. Trodden, 2006, "Modified-Constraint Gravity and Cosmological Structure Formation," *New J. Phys.*, **8**, 323; [astro-ph/0607458](#).
46. L. Ackerman, S.M. Carroll and M.B. Wise, 2007, "Imprints of a Primordial Preferred Direction on the Microwave Background," *Phys. Rev. D* **75**, 083502; [astro-ph/0701357](#).
47. S. M. Carroll and H. Tam, 2008, "Aether Compactification," *Phys. Rev. D* **78**, 044047; [arXiv:0802.0521](#).
48. A.L. Erickcek, M. Kamionkowski and S.M. Carroll, 2008, "A Hemispherical Power Asymmetry from Inflation," *Phys. Rev. D* **78**, 123520; [arxiv:0806.0377](#).
49. S.M. Carroll, S. Mantry, M.J. Ramsey-Musolf, and C.W. Stubbs, 2008, "Dark-Matter-Induced Weak Equivalence Principle Violation," *Phys. Rev. Lett.* **103**, 011301; [arxiv:0807.4363](#).
50. A.L. Erickcek, S.M. Carroll, and M. Kamionkowski, 2008, "Superhorizon Perturbations and the Cosmic Microwave Background," *Phys. Rev. D* **78**, 083012; [arxiv:0808.1570](#).
51. L. Ackerman, M.R. Buckley, S.M. Carroll, and M. Kamionkowski, 2008, "Dark Matter and Dark Radiation," *Phys. Rev. D* **79**, 023519; [arxiv:0810.5126](#).
52. S.M. Carroll, C.-Y. Tseng, and M.B. Wise, 2008, "Translational Invariance and the Anisotropy of the Cosmic Microwave Background," *Phys. Rev. D* **81**, 083501; [arxiv:0811.1086](#).
53. S.M. Carroll, 2008, "What if Time Really Exists?," entry in the Foundational Questions Institute Essay Competition on the Nature of Time; [arxiv:0811.3772](#).
54. S.M. Carroll, T.R. Dulaney, M. Gresham, and H. Tam, 2008, "Instabilities in the Aether", *Phys. Rev. D*, **79**, 065011; [arxiv:0812.1049](#).
55. S.M. Carroll, T.R. Dulaney, M. Gresham, and H. Tam, 2008, "Sigma-Model Aether", *Phys. Rev. D* **79**, 065012; [arxiv:0812.1050](#).
56. S.M. Carroll, M.C. Johnson, and L. Randall, 2009, "Extremal Limits and Black Hole Entropy," *JHEP* **0911**, 109; [arxiv:0901.0931](#).

(research publications cont.)

57. S.M. Carroll, S. Mantry, and M.J. Ramsey-Musolf, 2009, "Implications of a Scalar Dark Force for Terrestrial Experiments," *Phys. Rev. D* **81**, 063507; [arxiv:0902.4461](#).
58. S.M. Carroll, M.C. Johnson, and L. Randall, 2009, "Dynamical compactification from de Sitter space," *JHEP* **0911**, 094; [arxiv:0904.3115](#).
59. S.M. Carroll, H. Tam, and I.K. Wehus, 2009, "Lorentz Violation in Goldstone Gravity," *Phys. Rev. D* **80**, 025020; [arxiv:0904.4680](#).
60. B. Kloppenborg *et al.* [17 authors], 2010, "In the Shadow of the Transiting Disk: Imaging epsilon Aurigae in Eclipse," *Nature* **464**, 870; [arxiv:1004.2464](#).
61. S.M. Carroll and H. Tam, 2010, "Unitary Evolution and Cosmological Fine-Tuning," [arxiv:1007.1417](#).
62. A. Aguirre, S.M. Carroll, and M.C. Johnson, 2011, "Out of equilibrium: understanding cosmological evolution to lower-entropy states," *JCAP* **1202**, 024; [arxiv:1108.0417](#).
63. K. Boddy, S.M. Carroll, and M. Trodden, 2012, "Dark Matter with Density-Dependent Interactions," *Phys. Rev. D*, **86**, 123529; [arxiv:1208.4376](#).
64. S.M. Carroll, 2012, "Does the Universe Need God?," in *The Blackwell Companion to Science and Christianity*, ed. J.B. Stump and A.G. Padgett (Wiley-Blackwell: West Sussex, UK), p. 185.
65. K.K. Boddy and S.M. Carroll, 2013, "Can the Higgs Boson Save Us From the Menace of the Boltzmann Brains?" [arxiv:1308.4686](#).
66. G.N. Remmen and S.M. Carroll, 2013, "Attractor Solutions in Scalar-Field Cosmology," *Phys. Rev. D* **88**, 083518; [arxiv:1309.2611](#).
67. S.M. Carroll, S. Leichenauer, and J. Pollack, 2013, "A Consistent Effective Theory of Long-Wavelength Cosmological Perturbations," *Phys. Rev. D* **90**, 023518; [arxiv:1310.2920](#).
68. S.M. Carroll and C.T. Sebens, 2013, "Many Worlds, The Born Rule, and Self-Locating Uncertainty," in *Quantum Theory: A Two-Time Success Story, Yakir Aharonov Festschrift*, D.C. Struppa, J.M. Tollaksen, eds. (Springer-Verlag), p. 157; [arxiv:1405.7907](#).
69. C.T. Sebens and S.M. Carroll, 2014, "Self-Locating Uncertainty and the Origin of Probability in Everettian Quantum Mechanics," *The British Journal for the Philosophy of Science* **69**, 25; [arxiv:1405.7577](#).
70. K.K. Boddy, S.M. Carroll, and J. Pollack, 2014, "De Sitter Space Without Dynamical Quantum Fluctuations," *Found. Phys.* **46**, 702; [arxiv:1405.0298](#).
71. G.N. Remmen and S.M. Carroll, 2014, "How Many e -Folds Should We Expect from High-Scale Inflation?" *Phys. Rev. D* **90**, 063517; [arxiv:1405.5538](#).
72. S. Aaronson, S.M. Carroll, and L. Ouellette, 2014, "Quantifying the Rise and Fall of Complexity in Closed Systems: The Coffee Automaton," [arxiv:1405.6903](#).
73. S.M. Carroll, 2014, "In What Sense Is the Early Universe Fine-Tuned?," in *The Probability Map of the Universe*, B. Loewer, E. Winsberg and B. Weslake, eds. (Harvard University Press); [arxiv:1406.3057](#).
74. N. Bao, C. Cao, S.M. Carroll, A. Chatwin-Davies, N. Hunter-Jones, J. Pollack, and G.N. Remmen, 2015, "Consistency Conditions for an AdS/MERA Correspondence," *Phys. Rev. D* **91**, 125036; [arxiv:1504.06632](#).

(research publications cont.)

75. K.K. Boddy, S.M. Carroll, and J. Pollack, 2015, "Why Boltzmann Brains Don't Fluctuate Into Existence From the De Sitter Vacuum," in *The Philosophy of Cosmology*, K. Chamcham, J. Silk, J.D. Barrow, and S. Saunders, ed. (Cambridge University Press); [arxiv:1505.02780](#).
76. A. Chatwin-Davies, A.S. Jermyn, and S.M. Carroll, 2015, "How to Recover a Qubit That Has Fallen Into a Black Hole," *Phys. Rev. Lett.* **115**, 261302; [arXiv:1507.03592](#).
77. A. Bartolotta, S.M. Carroll, S. Leichenauer, and J. Pollack, 2015, "The Bayesian Second Law of Thermodynamics," *Phys. Rev. E* **94**, 022102; [arxiv:1508.02421](#).
78. S.M. Carroll and G.N. Remmen, 2016, "What is the Entropy in Entropic Gravity?" *Phys. Rev. D* **93**, 124052; [arxiv:1601.07558](#).
79. C. Cao, S.M. Carroll, and S. Michalakis, 2016, "Space from Hilbert Space: Recovering Geometry from Bulk Entanglement," *Phys. Rev. D* **95**, 024031; [arxiv:1606.08444](#).
80. K.K. Boddy, S.M. Carroll, and J. Pollack, 2016, "How Decoherence Affects the Probability of Slow-Roll Eternal Inflation," *Phys. Rev. D* **96**, 023539; [arxiv:1612.04894](#).
81. S.M. Carroll, 2017, "Why Boltzmann Brains Are Bad," in *Current Controversies in the Philosophy of Science*, S. Dasgupta, R. Dotan, and B. Weslake, eds. (Routledge), pp. 7-20; [arxiv:1702.00850](#).
82. N. Bao, C. Cao, S.M. Carroll, and L. McAllister, 2017, "Quantum Circuit Cosmology: The Expansion of the Universe Since the First Qubit," [arxiv:1702.06959](#).
83. S.M. Carroll and A. Chatwin-Davies, 2017, "Cosmic Equilibration: A Holographic No-Hair Theorem from the Generalized Second Law," *Phys. Rev. D* **97**, 046012; [arxiv:1703.09241](#).
84. S.M. Carroll and G.N. Remmen, 2017, "A Nonlocal Approach to the Cosmological Constant Problem," *Phys. Rev. D* **95**, 123504; [arxiv:1703.09715](#).
85. N. Bao, S.M. Carroll, and A. Singh, 2017, "The Hilbert Space of Quantum Gravity is Locally Finite-Dimensional," *Intl. J. Mod. Phys. D* **26**, 1743013; [arxiv:1704.00066](#).
86. A. Singh and S.M. Carroll, 2017, "Quantum Decimation in Hilbert Space: Coarse-Graining without Structure," *Phys. Rev. A* **97**, 032111; [arxiv:1709.01066](#).
87. N. Bao, C. Cao, S.M. Carroll, and A. Chatwin-Davies, 2017, "De Sitter Space as a Tensor Network: Cosmic No-Hair, Complementarity, and Complexity," *Phys. Rev. D* **96**, 123536; [arxiv:1709.03513](#).
88. C. Cao and S.M. Carroll, 2017, "Bulk Entanglement Gravity without a Boundary: Towards Finding Einstein's Equation in Hilbert Space," *Phys. Rev. D* **97**, 086003; [arxiv:1712.02803](#).
89. N. Bao, S.M. Carroll, A. Chatwin-Davies, J. Pollack, and G. Remmen, 2017, "Branches of the Black Hole Wave Function Need Not Contain Firewalls," *Phys. Rev. D* **97**, 126014; [arxiv:1712.04955](#).
90. S.M. Carroll and A. Singh, 2018, "Mad-Dog Everettianism: Quantum Mechanics at Its Most Minimal," in *What Is Fundamental?*, ed. A. Aguirre, B. Foster, and Z. Merali (Springer), p. 95. [arxiv:1801.08132](#).
91. S.M. Carroll, 2018, "Purpose, Freedom, and the Laws of Physics," in *Neuroexistentialism: Meaning, Morals, and Purpose in the Age of Neuroscience*, G. Caruso and O. Flanagan, eds. (Oxford University Press), p. 298.
92. A. Singh and S.M. Carroll, 2018, "Modeling Position and Momentum in Finite-Dimensional Hilbert Spaces via Generalized Clifford Algebra," [arxiv:1806.10134](#).

(research publications cont.)

93. S.M. Carroll, 2018, "Beyond Falsifiability: Normal Science in a Multiverse," in *Epistemology of Fundamental Physics: Why Trust a Theory?*, R. Dawid, R. Dardashti, and K. Thébault, eds. (Cambridge), pp. 300-314; [arxiv:1801.05016](https://arxiv.org/abs/1801.05016).
94. S.M. Carroll, 2018, "Why Is There Something Rather than Nothing?" in *The Routledge Companion to the Philosophy of Physics*, E. Knox and A. Wilson, eds. (Routledge), pp. 691-706; [arxiv:1802.02231](https://arxiv.org/abs/1802.02231).
95. S.M. Carroll and A. Singh, 2020, "Quantum Mereology: Factorizing Hilbert Space into Subsystems with Quasi-Classical Dynamics," *Phys. Rev. A* **103**, 022213; [arxiv:2005.12938](https://arxiv.org/abs/2005.12938).
96. S.M. Carroll, 2021, "The Quantum Field Theory on Which the Everyday World Supervenes," in *Levels of Reality: A Scientific and Metaphysical Investigation* (Jerusalem Studies in Philosophy and History of Science), O. Shenker, M. Hemmo, S. Iannidis, and G. Vishne, eds., pp. 27-46 (Springer); [arxiv:2101.07884](https://arxiv.org/abs/2101.07884).
97. S.M. Carroll and J. Lodman, 2021, "Energy Non-Conservation in Quantum Mechanics," *Found. Phys.* **51**, 83; [arxiv:2101.11052](https://arxiv.org/abs/2101.11052).
98. S.M. Carroll, 2021, "Reality as a Vector in Hilbert Space," *Quantum Mechanics and Fundamentality: Naturalizing Quantum Theory between Scientific Realism and Ontological Indeterminacy*, ed. V. Allori. (Synthese Library), pp. 211-224; [arxiv:2103.09780](https://arxiv.org/abs/2103.09780).
99. S.M. Carroll, 2021, "Consciousness and the Laws of Physics," *Journal of Consciousness Studies* **28**, pp. 16-31(16); philarchive.org/archive/CARCAT-31.
100. S.M. Carroll, 2023, "Reality Realism," *Analysis Reviews*, submitted.

Review Articles

1. S.M. Carroll, W.H. Press and E.L. Turner, 1992, "The Cosmological Constant," *Ann. Rev. Astron. Astrophys.* **30**, 499.
2. S.M. Carroll, 2000, "TASI Lectures: Cosmology for String Theorists," Lectures at the 1999 Theoretical Advanced Study Institute at the University of Colorado, Boulder; [hep-th/0011110](#).
3. S.M. Carroll, 2001, "The Cosmological Constant," *Living Reviews in Relativity* **4**, 1; [astro-ph/0004075](#).
4. S.M. Carroll, 2001, "Dark Energy and the Preposterous Universe," invited contribution to the SNAP (SuperNova Acceleration Probe) Yellow Book; [astro-ph/0107571](#).
5. D.S. Akerib, S.M. Carroll, M. Kamionkowski and S. Ritz, "Particle astrophysics and cosmology: Cosmic laboratories for new physics (Summary of the Snowmass 2001 P4 working group)," in *Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001)* ed. N. Graf, eConf **C010630**, P4001 (2001); [hep-ph/0201178](#).
6. S.M. Carroll, 2003, "Why is the Universe Accelerating?" Carnegie Observatories Astrophysics Series, Vol. 2: Measuring and Modeling the Universe, ed. W. L. Freedman (Cambridge: Cambridge Univ. Press); [astro-ph/0310342](#).
7. M. Trodden and S.M. Carroll, 2004, "TASI Lectures: Introduction to Cosmology," Lectures at the 2002 and 2003 Theoretical Advanced Study Institutes at the University of Colorado, Boulder; [astro-ph/0401547](#).
8. R. Bean, S.M. Carroll and M. Trodden, 2005, "Insights into Dark Energy: Interplay Between Theory and Observation," white paper submitted to the Dark Energy Task Force; [astro-ph/0510059](#).
9. S. Dodelson *et al.* [212 authors], 2009, "The Origin of the Universe as Revealed Through the Polarization of the Cosmic Microwave Background," Science White Paper submitted to the US Astro2010 Decadal Survey; [arXiv:0902.3796](#).

Books

1. S.M. Carroll, 2003, *Spacetime and Geometry: An Introduction to General Relativity* (Addison-Wesley).
2. S.M. Carroll, 2010, *From Eternity to Here: The Quest for the Ultimate Theory of Time* (Dutton). Editions in Bulgarian, English, Hebrew, Hungarian, Italian, Persian, Polish, Spanish, Russian, Turkish.
3. S.M. Carroll, 2012, *The Particle at the End of the Universe: How the Search for the Higgs Boson Leads Us to the Edge of a New World* (Dutton). Editions in Bulgarian, Chinese, Croatian, Czech, English, Finnish, French, Italian, Korean, Polish, Portuguese, Russian, Spanish, Ukrainian.
4. S.M. Carroll and W.L. Craig (authors), R.B. Stewart (editor), 2016, *God and Cosmology* (Greer-Hard Lectures).
5. S.M. Carroll, 2016, *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself* (Dutton). Editions in Arabic, Chinese, Finnish, Japanese, Korean, Polish, Romanian, Russian, Spanish, Turkish, Ukrainian.
6. S.M. Carroll, 2019, *Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime* (Dutton).
7. S.M. Carroll, 2022, *The Biggest Ideas in the Universe: Space, Time, and Motion* (Dutton).

Lecture Courses

1. S.M. Carroll, 2007, *Dark Matter, Dark Energy: the Dark Side of the Universe* (The Great Courses).
2. S.M. Carroll, 2012, *Mysteries of Modern Physics: Time* (The Great Courses).
3. S.M. Carroll, 2015, *The Higgs Boson and Beyond* (The Great Courses).

Other Publications

1. S.M. Carroll, 1997, *Lecture Notes on General Relativity*, [gr-qc/9712019](#).
2. S.M. Carroll, 2000, "Cosmological Constant", *Encyclopedia of Astronomy and Astrophysics*, P. Murdin, editor (Institute of Physics Publishing: London).
3. S.M. Carroll, 2000, "Is the Universe Still Accelerating?", *Matters of Gravity* **15**, 29; [gr-qc/0002027](#).
4. S.M. Carroll, 2000, "Cosmic microwave background anisotropies: tantalizingly close to expectations", *Matters of Gravity* **16**, 3; [gr-qc/0009060](#).
5. S.M. Carroll, 2002, Review of *Time Travel in Einstein's Universe* by J. Richard Gott, *Physics Today*, July 2002, p. 60.
6. S.M. Carroll, 2002, Review of *The Extravagant Universe* by Robert P. Kirshner, *Nature*, 24 October 2002, p. 784.
7. S.M. Carroll, 2003, "Filling in the background" (News and Views on *WMAP*), *Nature*, 6 March 2003, p. 26.
8. S.M. Carroll, 2003, Review of *Echo of the Big Bang* by Michael Lemonick, *Nature*, 24 July 2003, p. 373.
9. S.M. Carroll, 2003, "Quantum Gravity: An Astrophysical Constraint" (News and Views on Lorentz violation), *Nature*, 28 August 2003, p. 1007.
10. S.M. Carroll, 2004, "Insignificance" (Concepts essay on dark matter and dark energy), *Nature*, 6 May 2004, p. 27.
11. S.M. Carroll, 2004, "Cosmology Primer," <http://preposterousuniverse.com/writings/cosmologyprimer/>.
12. S.M. Carroll, 2005, "Dark Energy and the Preposterous Universe," *Sky and Telescope*, March 2005, p. 32.
13. S.M. Carroll, 2005, "Review of *The Future of Theoretical Physics and Cosmology: Celebrating Stephen Hawking's 60th Birthday*," eds. G. W. Gibbons, E. P. S. Shellard, and S. J. Rankin, *Am. J. Phys.* **73**, 479.
14. S.M. Carroll, 2005, "60 Seconds: Extra Dimensions," *symmetry*, June/July 2005, back cover.
15. S.M. Carroll, 2005, Review of *Warped Passages* by Lisa Randall and *Parallel Worlds* by Michio Kaku, *American Scientist* **93**, 550, November-December 2005.
16. S.M. Carroll, 2005, "Cosmological Constant," *World Book Online Reference Center*, 20 October 2005.
17. S.M. Carroll, 2006, "Welcome to the Blogosphere," *APS News*, May 2006, p. 12.
18. S.M. Carroll, 2006, "Time Before Time," *Seed*, September 2006, p. 43.
19. S.M. Carroll, 2006, "Focus on Dark Energy," *New Journal of Physics*, **8**.
20. S.M. Carroll, 2006, "Review: *The Trouble With Physics* by Lee Smolin," *New Scientist*, 30 September 2006, issue 2571, p. 58.
21. S.M. Carroll, 2006, "The Universe, Too Quickly Toured," review of *The Quantum Zoo* by Marcus Chown, *Science* **313**, 1391.

(other publications cont.)

22. S.M. Carroll, 2006, "Dark Matter is Real," *Nature Physics* **2**, 653.
23. S.M. Carroll, 2007, " Blogging for Physics," *Physics World*, Jan. 2007, p. 14.
24. S.M. Carroll, 2007, "Quantum Interrogation," in *The Open Laboratory: The Best Writing on Science Blogs 2006*, ed. B. Zivkovic (Lulu: Morrisville, NC), p. 123.
25. S.M. Carroll, 2007, "String Theory: It's Not Dead Yet," *New Scientist*, 19 May 2007, p. 25.
26. S.M. Carroll, 2008, "Being a Heretic is Hard Work," *Edge World Question Center 2008*.
27. S.M. Carroll, 2008, "Take the tube for the voyage of your lifetime," review of *The New Time Travelers* by David Toomey, *Times Higher Education Supplement*, 4 January 2008.
28. S.M. Carroll, 2008, "Pulling Power," review of *The Universal Force: Gravity, Creator of Worlds* by Louis A. Girifalco, *Nature* **451**, 130.
29. S.M. Carroll, 2008, "The Universe is Structured Like a Language," "The Cash Value of Astronomical Ideas," and "Dark Matter Exists," reprinted in *Ultimate Blogs: Masterworks from the Wild Web*, ed. Sarah Boxer (Vintage: New York), p. 42.
30. S.M. Carroll, 2008, "The Rise and Fall of Time," in *Year Million: Science at the Far Edge of Knowledge*, ed. Damien Broderick (Atlas: New York), p. 253.
31. S.M. Carroll, 2008, "The Cosmic Origins of Time's Arrow," *Scientific American*, June 2008, p. 48.
32. S.M. Carroll, 2008, "Lost in Space," review of *The Black Hole War* by Leonard Susskind, *The Wall Street Journal*, 28 July 2008.
33. S.M. Carroll, 2009, "Being a Heretic is Hard Work," in *What Have You Changed Your Mind About?*, ed. John Brockman (Harper Perennial: New York).
34. S.M. Carroll, 2009, "The First Quantum Cosmologist," in *The Open Laboratory 2008*, ed. Jennifer Rohn (Lulu: Morrisville, NC), p. 54.
35. S.M. Carroll, 2009, "Our Place in an Unnatural Universe," in *What's Next: Dispatches on the Future of Science*, ed. Max Brockman (Vintage: New York).
36. S.M. Carroll, 2009, "Why Not?," in *50 Voices of Disbelief: Why We Are Atheists*, ed. R. Blackford and U. Schuklenk (Wiley-Blackwell: New York).
37. S.M. Carroll, 2010, "How to Travel Through Time," *Discover*, March 2010.
38. S.M. Carroll, 2010, "The Elastic Universe," in *Findings on Elasticity*, ed. H. Aardse and A. van Baalen (Pars Foundation, Lars Muller Publishers: Amsterdam), p. 194.
39. S.M. Carroll, 2010, "The Grid of Disputation," in *The Open Laboratory 2009*, ed. Scicurious (Lulu: Morrisville, NC), p. 71.
40. S.M. Carroll, 2010, "Time and Change in an Eternal Universe," in *One Book, The Whole Universe: Plato's Timaeus Today*, ed. R.D. Mohr and B.M. Sattler (Parmenides Publishing: Las Vegas), p. 373.
41. S.M. Carroll, 2010, "The 'Why?' Questions, Chapter and Multiverse," review of *The Grand Design* by Stephen Hawking and Leonard Mlodinow, *The Wall Street Journal*, 24 September 2010, p. W17.
42. S.M. Carroll, 2011, "Calling You On Your Crap," in *Is The Internet Changing The Way You Think?*, ed. J. Brockman (Harper Perennial: New York), p. 111.

(other publications cont.)

43. S.M. Carroll, 2011, "Welcome to the Multiverse," *Discover*, October 2011.
44. S.M. Carroll, 2011, "Physics and the Immortality of the Soul," *Free Inquiry*, October/November 2011, p. 48.
45. S.M. Carroll, 2011, "Are There Mysterious Forces Lurking in Our Atoms and Galaxies?" *Discover*, November 2011.
46. S.M. Carroll, 2011, "Unwinding Time," *The Wall Street Journal*, December 18, 2011.
47. S.M. Carroll, 2012, "The Pointless Universe," in *This Will Make You Smarter: New Scientific Concepts to Improve Your Thinking*, ed. J. Brockman (Harper Perennial: New York), p. 9.
48. S.M. Carroll, 2012, "After the Higgs Boson: What Scientists Will Do With the Discovery," *The Daily Beast*, <http://thebea.st/MP09Sa>, July 6, 2012.
49. S.M. Carroll, 2012, "How the Higgs can lead us to the dark universe," CNN.com, <http://bit.ly/Q9SWPe>, July 24, 2012.
50. S.M. Carroll, 2012, "Digging Up the Early Universe," *Discover*, October 2012, p. 74.
51. S.M. Carroll, 2012, "Ask Me Anything," *Reddit.com*, <http://bit.ly/TD6Yq1>, 13 Nov. 2012.
52. S.M. Carroll, 2013, "Physics Enters a New Era," *Popular Science*, January 2013.
53. S.M. Carroll, 2013, "Einstein Explains that Gravity Is Universal," in *This Explains Everything: Deep, Beautiful, and Elegant Theories of How the World Works*, ed. J. Brockman (Harper Perennial: New York), p. 40.
54. S.M. Carroll, 2013, "Foreword," *The Realm of the Nebulae*, E. Hubble (Yale University Press: New Haven), p. xiii.
55. S.M. Carroll, 2013, "Science and Religion Can't Be Reconciled," *Slate*, <http://slate.me/13FGYjx>, 9 May 2013.
56. D. Goldberg and S.M. Carroll, 2013, "When Talking About Science, We Need More Tony Stark and Less Big Bang Theory," *Wired.com*, <http://bit.ly/1609Jeo> 2 August 2013.
57. S.M. Carroll, 2013, "Philosophy from the Preposterous Universe," interview with Richard Marshall, *3:AM Magazine*, <http://bit.ly/13CIS2G>, 3 August 2013.
58. S.M. Carroll, 2013, "No Physicist Is an Island," *New York Times* online and *International Herald Tribune*, 8 October 2013.
59. S.M. Carroll, 2013, "The Nobel Prize for Peter Higgs recognises truth in an ancient Greek idea," *The Independent* (UK), 10 December 2013.
60. S.M. Carroll, 2014, "When Nature Looks Unnatural," *New York Times* Opinionator online, 23 March 2014.
61. S.M. Carroll, 2014, "Five Questions Interview," in *Science and Religion: 5 Questions*, ed. G.D. Caruso (Automatic Press), p. 25.
62. S.M. Carroll, 2014, "What BICEP Found," *Engineering and Science*, Summer 2014, p. 17.
63. S.M. Carroll, 2014, "Why Does the Universe Look the Way it Does?," in *The Universe: Leading Scientists Explore the Origin, Mysteries and Future of the Cosmos*, ed. J. Brockman (Harper Perennial), p. 94.
64. S.M. Carroll, 2014, "Afterword," in *Twins in Time*, Z. Weinersmith and C. Jones (Little Universe).

(other publications cont.)

65. S.M. Carroll, 2015, "What Does 'Happy New Year' Even Mean?", *Smithsonian Magazine*, January 2015.
66. S.M. Carroll, 2015, "Falsifiability," in *This Idea Must Die*, ed. J. Brockman (Harper Perennial), p. 124.
67. S.M. Carroll, 2015, review of *Time in Powers of Ten*, by G. 't Hooft and S. Vandoren, *Am. J. Phys* **83**, 95.
68. S.M. Carroll, 2015, "We Are All Machines That Think," in *What to Think About Machines That Think: Today's Leading Thinkers on the Age of Machine Intelligence*, ed. J. Brockman (Harper Perennial), p. 56.
69. S.M. Carroll, 2016, "All Physics Is Local," *The Atlantic* online, <http://theatl.n.tc/2GvyW6l>, 12 Feb. 2016.
70. S.M. Carroll, 2016, "Zombies Must Be Dualists," *Nautilus*, 037, <http://bit.ly/1Pwf1Be>, 16 June 2016.
71. S.M. Carroll, 2017, "We Know All the Particles and Forces We're Made Of," in *Know This: Today's Most Interesting and Important Scientific Ideas, Discoveries, and Developments*, ed. J. Brockman (Harper Perennial), p. 121.
72. S.M. Carroll, 2017, "Cosmic Uncertainty: Your Skull Is an Amazing Physics Lab," *New Scientist*, <http://bit.ly/2mgyfFD>, 6 March 2017.
73. S.M. Carroll, 2017, "The Big Bang—or the Big Bounce?," *Financial Times*, <http://on.ft.com/2GxzUin>, 17 March 2017.
74. S.M. Carroll, 2017, "Marching for the Right to Be Wrong," *The Atlantic* online, <http://theatl.n.tc/2D0IozQ>, 21 April 2017.
75. S.M. Carroll, 2018, "Bayes's Theorem," in *This Idea Is Brilliant: Lost, Overlooked, and Underappreciated Science Everyone Should Know*, ed. J. Brockman (Harper Perennial), p. 297.
76. S.M. Carroll, 2018, "In Memoriam: Joe Polchinski, 1954–2018," *Scientific American* online, <http://bit.ly/2nUtcu1>, 8 February 2018.
77. S.M. Carroll, 2018, "Foreword," in *Alice and Bob Meet the Wall of Fire: Science from Quanta*, ed. T. Lin (MIT Press).
78. S.M. Carroll, 2018, "Stephen Hawking's Most Profound Gift to Physics," *The New York Times* online, <http://nyti.ms/2DADqWz>, 15 March 2018.
79. S.M. Carroll, 2018, "Stephen Hawking Was Very Particular About His Tea," *The Atlantic* online, <http://theatl.n.tc/2plePQk>, 16 March 2018.
80. S.M. Carroll, 2019, "Mindscape Podcast: Philosophy Outside Academia," *Blog of the APA*, <http://bit.ly/31VH89U>, 16 January 2019.
81. S.M. Carroll, 2019, "Reality Remains Intact," *Daily Nous*, <http://bit.ly/2KMTzyR>, 21 March 2019.
82. S.M. Carroll, 2019, "The Physicist Who Made Sense of the Universe," *The New York Times* online, <https://nyti.ms/2YRm3vx>, 28 May 2019.
83. S.M. Carroll, 2019, "Foreword," in *Fire, Ice, and Physics: The Science of Game of Thrones*, R.C. Thompson (MIT Press).

(other publications cont.)

84. S.M. Carroll, 2019, "Even Physicists Don't Understand Quantum Mechanics," *The New York Times*, <https://nyti.ms/31kTQ1X>, 7 September 2019.
85. S.M. Carroll, 2019, "Where Quantum Probability Comes From," *Quanta*, <http://bit.ly/31kTMzf>, 9 September 2019.
86. S.M. Carroll, 2019, "Woven from Weirdness" *New Scientist* **243**, 34-38, <http://bit.ly/31srXF6>, 14 September 2019.
87. S.M. Carroll, 2019, "Splitting the Universe," *Aeon*, <http://bit.ly/2kNf8oK>, 11 September 2019.
88. S.M. Carroll, 2019, "The Big Idea: Sean Carroll," *Whatever*, <http://bit.ly/2k1D7eI>, 12 September 2019.
89. S.M. Carroll, 2019, "If You Existed in Multiple Universes, How Would You Act In This One?," *Literary Hub*, <http://bit.ly/2140k3B>, 23 September 2019.
90. S.M. Carroll, 2020, "Time: Introduction," *InterPlanetary Transmissions: Stardust* (Proceedings of the Santa Fe Institute's Second InterPlanetary Festival), eds. D.C. Krakauer and C.L. McShea (SFI Press).
91. S.M. Carroll, 2022, "Addressing the Quantum Measurement Problem," *Physics Today* **75**, 62-64.