

Sean M. Carroll

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Current Positions

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

Research Interests

Theoretical physics. Quantum mechanics, spacetime, cosmology, field theory, gravitation, thermodynamics, 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 [36, 46, 54,55]. I have developed frameworks in which to analyze possible large-scale deviations from cosmological isotropy [46, 48, 50, 52].

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, 49, 57, 63], including the possibility of an unbroken analogue of electromagnetism in the dark sector [51].

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 [35, 38, 45]. 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, 34, 43] 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 [39,41]. I have developed measures of cosmological fine-tuning [61, 66, 71, 73], and studied the possibility of the universe fluctuating into a proto-inflationary state [62]. I showed for the first time how cosmic evolution could spontaneously compactify dimensions of spacetime [58].

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 [68,69]. 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 [70]. I proposed an algorithm for decomposing Hilbert space into system+environment [95]. I also pointed out that average energy is not conserved in quantum measurements, and proposed an experimental test [97].

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" [90,98]. The geometry of space can be defined by the entanglement of Hilbert-space factors [79], and Einstein's equation for gravity emerges from a requirement of entanglement equilibrium [88].

Statistical Mechanics and Complexity I have argued that, while entropy increases in closed systems, natural measures of "complexity" first increase and then decrease [72]. 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 [77].

Honors and Awards

- 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, 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, Space Time, and Motion*: *New York Times* bestseller list, Best books of the year, Amazon.com
- 2024 Trotter Prize in Information, Complexity, and Inference, Texas A&M University
- 2024 *Quanta and Fields*: *New York Times* bestseller list
- 2024 Project Exploration STEM Champion Award

Named Lectures

- 2003 Malmstrom Lecturer, Hamline University
- 2003 Resnick Lecturer, Rensselaer Polytechnic Institute, 2003;
- 2007 National Science Foundation NSF Distinguished Lecturer, 2007;
- 2011 Kieval Lecturer, Cornell University, 2011;
- 2014 Brattain Lecturer, Whitman College, 2014;
- 2014 Keynote Address, American Humanist Association, 2014;
- 2014 Schrödinger Colloquium, Universität Zürich, 2014;
- 2016 Gifford Lectures in Natural Theology, Glasgow, 2016;
- 2017 Beyond Annual Lecture, Arizona State University, 2017;
- 2019 Patrick Suppes Lecture in Logic or Philosophy of Science, Columbia University, 2019;
- 2023 Musk Public Lecture, University of Pennsylvania, 2023;
- 2023 Ford Distinguished Lecture, University of Michigan, 2023;
- 2024 Norton Lecture in Philosophy, University of Delaware, 2024;
- 2025 Biard Cosmology and Astrophysics Lecture, Ohio State University, 2025;
- 2025 Cruikshank Lecture in Physics, University of Rhode Island, 2025.
- 2025 Klopsteg Memorial Lecture, American Association of Physics Teachers

Advising

- Undergraduate research/thesis students** Ethan Honda (MIT, 1996), Teodora Beloreshka (Caltech, 2000), Augusta Abrahamse (American University, 2002), Monica Guica (Chicago, 2003), Stefan Mendez-Diez (Chicago, 2004), Suz Tolwinski (Brown, 2004), Abhishek Kumar (Chicago, 2004), Nicholas Scianmarello (Caltech, 2010), Aliza Malz (Caltech, 2010), Kevin Kuns (Caltech, 2012), Mengshuen Chua (Caltech, 2015), Jackie Lodman (Caltech, 2020), Aychuth Parola (Johns Hopkins, 2024)
- 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), Christopher Shallue (Harvard, 2025), Nadiia Diachenko (Johns Hopkins, current)
- 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), Saakshi Dulani (Johns Hopkins, 2023-2026)

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
- 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
- 2024 Co-Organizer, Arrow of Time Workshop, Johns Hopkins Natural Philosophy Forum
- 2025 Co-Organizer, Natural Philosophy Symposium, Baltimore

Activities

- Professional Societies American Physical Society, American Philosophical Association, American Association for the Advancement of Science, Philosophy of Science Association, Authors Guild, Foundational Questions Institute, International Society for Quantum Gravity, Complex Systems Society, American Association of University Professors, PEN America
- 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 Faculty Board, Alexander Grass Humanities Institute, Johns Hopkins
- 2022-present Co-Founder and Co-Director, Natural Philosophy Forum, Johns Hopkins

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)

2023 First-Year seminar 001.194, The Arrow of Time (undergraduate)

2023 Philosophy 150.470, Philosophical Naturalism (undergraduate)

2024 Physics 171.115, Spacetime and Quanta (undergraduate)

2024 Philosophy 150.626, Complexity and Emergence (graduate)

Research Profiles and Citations

[Google Scholar](#)

[inSPIRE](#)

[PhilPeople](#)

[ORCID](#)

Film/Television Consulting (with main contacts)

- 2007 *Angels and Demons* (Ron Howard, director; Brian Grazer, producer)
- 2008, 2013 *Bones* (Janet Lin, writer; Emily Silver, writer)
- 2009 *TRON: Legacy* (Jeffrey Silver, producer; Joseph Kosinski, director)
- 2009 *Thor* (Kevin Feige, producer; Kenneth Branagh, director; Don Payne, writer)
- 2011 *Fringe* (Glen Whitman, writer)
- 2013 *Thor: The Dark World* (Kevin Feige, producer; Alan Taylor, director)
- 2014 *Big Hero Six* (Don Hall, director)
- 2015 *Terminator: Genysis* (Alan Taylor, director)
- 2016 *Spectral* (George Nolfi, writer)
- 2017 *Downsizing* (Alexander Payne, director)
- 2018 *Inversion* (Samuel Nozick, co-producer)
- 2019 *Avengers: Endgame* (Russo Brothers, writers/directors)
- 2021 *Halo* (Steven Kane, executive producer)
- 2025 *Avengers: Doomsday* (Russo Brothers, writers/directors)

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.
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