

Arvind Murugan

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Research Interests

I am interested in 'hardware' implementations (e.g., in biomolecules, reaction networks, self-assembly, soft materials) of behaviors usually seen in 'software' (e.g., error correction, inference, machine learning using neural networks). My work involves quantitative biology, materials design, non-equilibrium dynamics and theoretical computer science.

Employment

Assistant Professor	University of Chicago , Chicago, IL Physics + James Franck Institute	July 15 - (present)
Postdoc	Harvard University , Cambridge, MA School of Engineering and Applied Sciences	Sep 12 - Sep 15
Member	Institute for Advanced Study , Princeton, NJ School of Natural Sciences	Aug 09 - Aug 12
Visiting Researcher	Rockefeller University , NYC, NY Laboratory of Living Matter	Aug 09 - Aug 12

Education

Ph.D. (Physics)	Princeton University , Princeton, NJ Thesis: "Gauge-gravity duality with renormalization group flow and reduced supersymmetry." <i>Advisor: Igor R. Klebanov</i>	Sep 04 - Jul 09
M.S. (Physics)	California Institute of Technology , Pasadena, CA. <i>Advisor: Anton Kapustin</i>	Sep 00- Jun 04
B.S. (Mathematics)	California Institute of Technology , <i>w/ honors</i> Pasadena, CA.	Sep 00- Jun 04

Research articles

- * W. Pittayakanchit, Z. Lu, J. Chew, M. Rust, [A. Murugan](#)
“Trade-off between internal and external noise resistance sets clock attractor geometry”,
(under review)
- 18 N. Stern, M. Pinson, [A. Murugan](#),
“The complexity of folding self-folding origami”
Physical Review X 7, 041070 (2017)
- 17 W. Zhong, D. Schwab, [A. Murugan](#)
“Associative pattern recognition through macro-molecular self-assembly”
Journal of Statistical Physics, 167, Issue 3–4, (2017)
- 16 M. Pinson, M. Stern, A. Carruthers, B. Chen, [A. Murugan](#),
“Self-folding origami at any energy scale”
Nature Communications 8:15477 (2017)
- 15 [A. Murugan](#), S. Vaikuntanathan,
“Topologically protected modes in non-equilibrium stochastic systems”
Nature Communications 8, 13881 (2017)
- 14 M. Huntley*, [A. Murugan](#)*, M. Brenner (* = first authors)
“The Information Capacity of Specific Interactions”,
Proceedings of the National Academy of Sciences 113 (21) 5841-5846 (2016)
- 13 D. Zwicker, [A. Murugan](#)*, M. Brenner* (* = corresponding authors)
“Receptor arrays optimized for natural odor statistics”,
Proceedings of the National Academy of Sciences 113(20) 5570-5575 (2016)
- 12 [A. Murugan](#), S. Vaikuntanathan,
“Biological implications of dynamical phases in non-equilibrium networks”
Journal of Statistical Physics special issue (2016, 162 (6))
- 11 [A. Murugan](#)*, Z. Zeravcic*, S. Leibler, M. Brenner, (* = first authors)
“Multifarious Assembly Mixtures: Systems Allowing Retrieval of Diverse Stored Structures”,
Proceedings of the National Academy of Sciences 112(1) 54-59 (2015)
- 10 [A. Murugan](#)*, J. Zou*, and M. Brenner, (* = first authors)
“Undesired Usage and the Robust Self-Assembly of Heterogeneous Structures”
Nature Communications 6, 6203 (Jan 2015)
- 9 [A. Murugan](#), D.A. Huse, S. Leibler,
“Discriminatory proofreading regimes in non-equilibrium systems”
Physical Review X 4 (2), 021016

- 8 [A. Murugan](#), D.A. Huse, S. Leibler
"Speed, dissipation, and error in kinetic proofreading"
 Proceedings of the National Academy of Sciences 109(30):12034-9 (2012)
- 7 I.R.Klebanov, T.Klose, [A. Murugan](#)
"AdS4/CFT3 – squashed, stretched and warped"
 Journal of High Energy Physics 0903 140 (2009) arxiv:0809.3773 [hep-th]
- 6 I. R. Klebanov, [A. Murugan](#), D. Rodriguez-Gomez, J. Ward
"Goldstone Bosons and Global Strings in a Warped Resolved Conifold"
 Journal of High Energy Physics 0805, 090 (2008), arXiv:0712.2224 [hep-th]
- 5 I. R. Klebanov, D. Kutasov, [A. Murugan](#)
"Entanglement as a Probe of Confinement"
 Nuclear Physics B 796, 274 (2008), arXiv:0709.2140 [hep-th]
- 4 I. R. Klebanov, [A. Murugan](#),
"Gauge/Gravity Duality and Warped Resolved Conifold"
 Journal of High Energy Physics 0703, 042 (2007), arXiv:hep-th/0701064
- 3 D. Baumann, A. Dymarsky, I. R. Klebanov, J. M. Maldacena, L. McAllister, [A. Murugan](#)
"On D3-brane potentials in compactifications with fluxes and wrapped D-branes"
 Journal of High Energy Physics 0611, 031 (2006), arXiv:hep-th/0607050
- 2 A.Kapustin, [A. Murugan](#)
"Fatgraph expansion for noncritical superstrings"
 arXiv:hep-th/0404238
- 1 Hauksson, Egill, [A. Murugan](#)
"A new 3-D Regional Velocity Model for Real-time Hypocenter Determinations in Southern California"
 Proceedings of the Southern California Earthquake Center (Annual Meeting), 2002

Invited talks

APS Invited talk Los Angeles, CA	``Towards a theory of self-folding''	Mar'18
KITP, Santa Barbara, CA	Invited talk, Memories 2018 conference ``Associative memory in frustrated materials''	Feb'18
Princeton University, Princeton, NJ	Invited talk, PCTS workshop ``Associative memory in frustrated materials''	Nov'17
MIT Physics, Cambridge, MA	Physics seminar ``Internal models of the external world''	Oct'17
UT Southwestern, Dallas, TX	Systems Biology seminar ``Internal models of the external world''	Oct'17

Washington U. St Louis, MO	Physics seminar, ``Internal models of the external world''	Sep'17
QBio workshop, New Brunswick, NJ	``Continuous attractors as unreliable estimators''	Jul'17
CNLS conference Santa Fe, NM	Los Alamos NL annual conference "Fitting internal models to the external world"	May'17
Harvard University, Cambridge, MA	Widely Applied Math seminar "Fitting internal models to the external world"	Mar'17
Northwestern University, Chicago, IL	Mechanical Engineering, "When is something self-folding?"	Jan' 17
Harvard University, Cambridge, MA	Workshop on Aging and Failure in biology "Error correction through catastrophes"	May'16
Foundations of Nanoscience (FNANO), Snowbird, UT	Invited speaker "Control of heterogeneous self-assembly"	Apr'16
University of Illinois, Urbana-Champaign, IL	Urbana cond-mat Symposium, "Associative memory: A forgotten property of frustrated disordered materials"	Mar'16
Santa Fe Institute, Santa Fe, NM	Kinetic Networks: from Topology to Design, "More computation by matter"	Sep'15
Rockefeller University, New York, NY	Center for Studies in Physics and Biology, ``Control vs multi-functionality in disordered frustrated systems"	Apr'15
University of Colorado, Boulder, CO	Department of Physics, Colloquium "Design principles for heterogeneous structure synthesis: Lessons from biology"	Mar'15
University of Colorado, Boulder, CO	Department of Physics, Seminar "Non-equilibrium error correction in biological and synthetic systems"	Mar'15
APS Invited Talk, San Antonio, TX	"Non-equilibrium error correction in biological and synthetic systems"	Mar'15
University of Massachusetts, Amherst, Amherst, MA	Department of Physics, "Design principles for heterogeneous structure synthesis: Lessons from biology"	Mar'15
University of San Diego, San Diego, CA	Department of Physics, "Design principles for heterogeneous structures"	Feb'15
MIT, Cambridge, MA	Department of Physics, "Design principles for heterogeneous structure synthesis: Lessons from biology"	Feb'15

Aspen Institute for Physics, Aspen, CO	Unified Concepts in Glass Physics VI, "Associative memory: A forgotten property of marginal frustrated systems"	Feb'15
Cornell, Ithaca, NY	LASSP and Applied Physics seminar, "Design principles for heterogeneous structure synthesis: Lessons from biology"	Jan'15
University of Chicago, Chicago, IL	James Franck Institute, "Design principles for heterogeneous structure synthesis: Lessons from biology"	Jan'15
Princeton University, Princeton, NJ	Department of Chemistry, "Design principles for heterogeneous structure synthesis: Lessons from biology"	Dec'14
Universite Joseph Fourier, Grenoble, France	Laboratory of Interdisciplinary Physics, "Associative memory and bottom-up materials synthesis"	Jul'14
University of Nice, Nice, France	Laboratory of Condensed Matter Physics, "Associative memory and bottom-up materials synthesis"	Jun'14
Ecole Superieure de Physique et de Chimie Industrielles (ESPCI) , Paris	jointly with Ecole Normale Superieure (ENS), "Associative memory and bottom-up materials synthesis"	Jun'14
Brandeis, Waltham, MA	Physics Department "Design principles for heterogeneous materials synthesis: Lessons from biology"	Jun'14
University of Chicago, Chicago, IL	Computations in Science Seminar, "Design principles for heterogeneous materials synthesis: Lessons from biology."	May'14
University of Maryland College Park, MD	Institute for Physical Science and Technology, "Design principles for material synthesis : Lessons from biology"	Apr'14
Northwestern, Evanston, IL	Applied Math Colloquium "Design principles for material synthesis : Lessons from biology"	Jan'14
Boston Physical Biology Hangout, MIT	"Principles of non-equilibrium error-correction"	Dec'13
Harvard University, Cambridge, MA	Bauer Forum "Self-assembly in imperfect conditions" Condensed Matter Kids Seminar "Kinetic Proofreading and Non-Equilibrium Occupancy of States"	Nov'13 Oct'12 Dec'11

Perimeter Institute for Theoretical Physics, Ontario	Young Researchers Conference, "Gauge-gravity duality in 2 + 1 dimensions"	Dec'08
Institute for Nuclear Theory, U. Washington, Seattle, WA	String Theory Methods in the Real World, "Entanglement as a probe of confinement"	May'08
Princeton University, Princeton, NJ	High-energy theory group seminar, "Entanglement and Confinement"	Apr'08
Cornell University, Ithaca, NY	High-energy theory group seminar, "Entanglement and Confinement"	Apr'08
University of Chicago, Chicago, IL	High-energy theory group seminar, "Entanglement as a measure of confinement"	Nov'07

Awards

Simons Investigator, MMLS, 2017-2022

Addie and Harold Broitman Member in Biology, IAS 2010 - 2011.

Princeton University Graduate Centennial Fellowship 2004 - 2009.

Princeton University Joseph Henry Prize 2004.

Caltech Carnation Merit Award 2004

D.S.Kothari Prize for research in Physics (Caltech).

Herbert J.Ryser Scholarship in Mathematics (Caltech)

Caltech Carnation Merit Award (2002) and the Milton & Jane Mohr Scholarship (2001)

31st International Physics Olympiad (UK 2000), Gold Medal

Other research experience

CERN, Geneva	CMS experiment at the Large Hadron Collider , with Prof. Christopher Tully, Princeton Testing and calibrating hadron calorimetry of the Compact Muon Solenoid (CMS) particle detector.	Jun - Aug 04
Caltech	Matrix Models and String theory , with Prof. Anton Kapustin, Caltech, supported by SURF, Studied relations between Matrix Quantum Mechanics and string theory in 1 + 1 dimensional spacetime.	Jun - Aug 03

USGS & Caltech	Southern California Seismic Network , with Dr. Egill Hauksson, Caltech & U.S. Geological Survey Improving the seismic wave velocity model for Southern California by inverting earthquake and quarry data from seismometers.	Jun - Sep 02
Caltech	Energy deposition in metals by large molecules , with Prof. Tom Tombrello, supported by SURF, Caltech Theoretical research on Coulombic effects on C60 “Buckyballs” moving rapidly through metals.	Jun - Aug 01

Teaching experience

Fall 16, Fall 17	Mathematical Methods for Physicists , (U Chicago) Introductory mathematical methods for PhD students
Fall 15, Fall 17	Principles of Biophysics , Ph 490 (U Chicago) Introduction to quantitative biology for physics PhD students
Fall 06, 07, 08	Quantum Field Theory , Ph 509, (Princeton) with Prof. Alexander Polyakov, Introductory graduate level course for PhD students
Spring 06, 07	Electromagnetism , Ph 106, (Princeton) with Prof. Herman Verlinde, Second course in electromagnetism for potential physics majors.
Spring 05	Introductory Physics II , Ph 102, (Princeton) with Prof. Nai Phuan Ong, General physics labs in mechanics and optics for pre-medical students
Fall 05	Classical Mechanics , Ph 205 advanced, Ph 203 beginners (Princeton) with Prof. Steven Gubser & Prof. Michael Romalis Advanced topics in classical mechanics for physics majors.

Service/outreach

Referee	Referee for “PNAS”, “Nature Communications”, “Physical Biology”, “Biophysical Journal”, “PLoS One”, “Journal of the Royal Society Interface”, “Journal of High Energy Physics”, “Nuclear Physics B”, “Physical Review Letters, D, X”, “Journal of Statistical Physics”, “Quantum Information Processing”, “Journal of Nonlinear Science”
Organizer	Midwest QBio meeting (Nov 2015) at U Chicago. Organizer of APS March meeting (2017) session on information processing in biology.

Other outreach Judge, Princeton Undergraduate Research Symposium, May 4 2011
`Theory alley' display for high school students at annual Physics with a Bang U Chicago outreach event (2015 - 2017)
Workshop for science teachers at KITP, Santa Barbara (2018)

References

Prof. Stanislas Leibler, Rockefeller University/ IAS

Prof. Michael Brenner, Harvard University

Prof. John Hopfield, Princeton University

Prof. Igor Klebanov, Princeton University