89th Josiah Willard Gibbs Lecture

Wednesday, January 6, 2016
8:30–9:30 PM

JOSIAH WILLARD GIBBS 1839–1903

Photograph by Pictorial Mathematics
Scripta Mathematica
Yeshiva College, New York, 1942
To commemorate the name of Professor Gibbs, the American Mathematical Society established an honorary lectureship in 1923 to be known as the Josiah Willard Gibbs Lectureship. The lectures are of a semipopular nature and are given by invitation. They are usually devoted to mathematics or its applications. It is hoped that these lectures will enable the public and the academic community to become aware of the contribution that mathematics is making to present-day thinking and to modern civilization.
Abstract

I will explain how we use linear algebra to understand graphs and how recently developed ideas in graph theory have inspired progress in linear algebra.

Graphs can take many forms, from social networks to road networks, and from protein interaction networks to scientific meshes. One of the most effective ways to understand the large-scale structure of a graph is to study algebraic properties of matrices we associate with it. I will give examples of what we can learn from the Laplacian matrix of a graph.

We will use the graph Laplacian to define a notion of what it means for one graph to approximate another, and we will see that every graph can be well-approximated by a graph having few edges. For example, the best sparse approximations of complete graphs are provided by the famous Ramanujan graphs. As the Laplacian matrix of a graph is a sum of outer products of vectors, one for each edge, the problem of sparsifying a general graph can be recast as a problem of approximating a collection of vectors by a small subset of those vectors. The resulting problem appears similar to the problem of Kadison and Singer in Operator Theory. We will sketch how research on the sparsification of graphs led to its solution.
Daniel Alan Spielman received his B.A. in Mathematics and Computer Science from Yale in 1992, and his Ph.D. in Applied Mathematics from M.I.T. in 1995. He spent a year as an NSF Mathematical Sciences Postdoc in the Computer Science Department at U.C. Berkeley, and then taught in the Applied Mathematics Department at M.I.T. until 2005. Since 2006, he has been a Professor at Yale University. He is presently the Henry Ford II Professor of Computer Science, Mathematics, and Applied Mathematics.

He has received many awards, including the 1995 ACM Doctoral Dissertation Award, the 2002 IEEE Information Theory Paper Award, the 2008 Godel Prize, the 2009 Fulkerson Prize, the 2010 Nevanlinna Prize, the 2014 Polya Prize, an inaugural Simons Investigator Award, and a MacArthur Fellowship. He is a Fellow of the Association for Computing Machinery and a member of the Connecticut Academy of Science and Engineering. His main research interests include the design and analysis of algorithms, network science, machine learning, digital communications, and scientific computing.
Gibbs Lectures


18. November 1944, Chicago, Illinois; Professor John von Neumann, Institute for Advanced Study; *The ergodic theorem and statistical mechanics.*


22. December 1948, Columbus, Ohio; Professor Hermann Weyl, Institute for Advanced Study; *Ramifications, old and new, of the eigenvalue problem,* Bulletin of the American Mathematical Society, v. 56, no. 2, pp. 115–139 (1950).


24. December 1950, Gainesville, Florida; Professor G. E. Uhlenbeck, University of Michigan; *Some basic problems of statistical mechanics.*


26. December 1952, St. Louis, Missouri; Professor Marston Morse, Institute for Advanced Study; *Topology and geometrical analysis.*


33. January 1960, Chicago, Illinois; Professor Julian Schwinger, Harvard University; *Quantum field theory.*

34. January 1961, Washington, DC; Professor J. J. Stoker, Institute of Mathematical Sciences, New York University; *Some nonlinear problems in elasticity,* Bulletin of the American Mathematical Society, v. 68, no. 4, pp. 239–278 (1962). Published under the title *Some observations on continuum mechanics with emphasis on elasticity.*

35. January 1962, Cincinnati, Ohio; Professor C. N. Yang, Institute for Advanced Study; *Symmetry principles in modern physics.*

36. January 1963, Berkeley, California; Professor Claude E. Shannon, Massachusetts Institute of Technology; *Information theory.*

37. January 1964, Miami, Florida; Professor Lars Onsager, Yale University; *Mathematical problems of cooperative phenomena.*


40. January 1967, Houston, Texas; Professor Mark Kac, Rockefeller University; *Some mathematical problems in the theory of phase transitions*.


46. January 1973, Dallas, Texas; Professor Jürgen Moser, Courant Institute of Mathematical Sciences, New York University; *The stability concept in dynamical systems*.

47. January 1974, San Francisco, California; Professor Paul A. Samuelson, Massachusetts Institute of Technology, *Economics and mathematical analysis*.


49. January 1976, San Antonio, Texas; Professor Arthur S. Wightman, Princeton University; *Nonlinear functional analysis and some of its applications in quantum field theory*.


52. January 1979, Biloxi, Mississippi; Professor Martin Kruskal, Princeton University; “What are solitons and inverse scattering anyway, and why should I care?”

53. January 1980, San Antonio, Texas; Professor Kenneth Wilson, Cornell University; *The statistical continuum limit*.


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58. January 1985, Anaheim, California; Professor Michael O. Rabin, Harvard University, Cambridge, Massachusetts and Hebrew University, Jerusalem, Israel; *Randomization in mathematics and computer science*.

59. January 1986, New Orleans, Louisiana; Professor L. E. Scriven, University of Minnesota; *The third leg: Mathematics and computation in applicable science and high technology*.

60. January 1987, San Antonio, Texas; Professor Thomas C. Spencer, Courant Institute of Mathematical Sciences, New York University; *Schrödinger operators and dynamical systems*.


63. January 1990, Louisville, Kentucky; Professor George B. Dantzig, Stanford University, Stanford, California; *The wide wide world of pure mathematics that goes by other names*.


65. January 1992, Baltimore, Maryland; Professor Michael E. Fisher, Institute for Physical Sciences and Technology, University of Maryland, College Park, Maryland; *Approaching the limit: Mathematics and myth in statistical physics*.

66. January 1993, San Antonio, Texas; Professor Charles S. Peskin, Courant Institute of Mathematical Sciences, New York University; *Fluid dynamics and fiber architecture of the heart and its valves*.


68. January 1995, San Francisco, California; Professor Andrew J. Majda, Princeton University; *Turbulence, turbulent diffusion, and modern applied mathematics*.

69. January 1996, Orlando, Florida; Professor Steven Weinberg, University of Texas, Austin; *Is field theory the answer? Is string theory the answer? What was the question?*


73. January 2000, Washington, DC; Professor Roger Penrose, Mathematical Institute, Oxford University; *Physics, computability, and mentality*.

74. January 2001, New Orleans, Louisiana; Professor Ronald L. Graham, University of California, San Diego; *The Steiner problem*.

76. January 2003, Baltimore, Maryland; Professor David B. Mumford, Division of Applied Mathematics, Brown University, Providence, RI; *The shape of objects in two and three dimensions: Mathematics meets computer vision*.

77. January 2004, Phoenix, Arizona; Professor Eric S. Lander, Professor of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts; *Biology as information*.

78. January 2005, Atlanta, Georgia; Professor Ingrid Daubechies, Department of Mathematics and Program in Applied and Computational Mathematics, Princeton University, Princeton, New Jersey; *The interplay between analysis and algorithms*.

79. January 2006, San Antonio, Texas; Professor Michael A. Savageau, Department of Biomedical Engineering and Microbiology Graduate Group, University of California, Davis, California; *Function, design, and evolution of gene circuitry*.

80. January 2007, New Orleans, Louisiana; Professor Peter D. Lax, Courant Institute of Mathematical Sciences, New York University, New York, New York; *Mathematics and physics*.

81. January 2008, San Diego, California; Professor Avi Wigderson, Institute for Advanced Study, Princeton, New Jersey; *Randomness—A computational complexity view*.


83. January 2010, San Francisco, California; Professor Peter Shor, Massachusetts Institute of Technology; *Quantum channels and their capacities*.

84. January 2011, New Orleans, Louisiana; Professor George Papanicolaou, Stanford University; *Mathematical problems in systemic risk*.

85. January 2012, Boston, Massachusetts; Professor Bradley Efron, Stanford University; *A 250-year argument: Belief, behavior, and the bootstrap*.

86. January 2013, San Diego, California; Professor Cédric Villani, Institut Henri Poincaré; *On disorder, mixing, and equilibration*.

87. January 2014, Baltimore, Maryland; Professor Andrew Blake, Microsoft Research Cambridge; *Machines that see, powered by probability*.

88. January 2015, San Antonio, Texas; Professor Ronald L. Graham, University of California, San Diego, California; *Mathematics and computers: Problems and prospects*.

89. January 2016, Seattle, Washington; Professor Daniel A. Spielman, Yale University; *Graphs, vectors, and matrices*. 