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Lars Hernquist and Volker Springel Receive \$500,000 Gruber Cosmology Prize



Lars Hernquist



Volker Springel

New Haven, CT — The 2020 Gruber Cosmology Prize recognizes Lars Hernquist, Center for Astrophysics | Harvard & Smithsonian, and Volker Springel, Max Planck Institute for Astrophysics, for their defining contributions to cosmological simulations, a method that tests existing theories of, and inspires new investigations into, the formation of structures at every scale from stars to galaxies to the universe itself.

Hernquist and Springel will divide the \$500,000 award, and each will receive a gold laureate pin at a ceremony that will take place later this year. The award recognizes their transformative work on structure formation in the universe, and development of numerical algorithms and community codes further used by many other researchers to significantly advance the field.

Hernquist was a pioneer in cosmological simulations when he joined the fledgling field in the late 1980s, and since then he has become one of its most influential figures. Springel, who entered the field in 1998 and first partnered with Hernquist in the early 2000s, has written and applied several of the most widely used codes in cosmological research. Together Hernquist and Springel constitute, in the words of one Gruber Prize nominator, “one of the most productive collaborations ever in cosmology.”

Computational simulations in cosmology begin with the traditional source of astronomical data: observations of the universe. Then, through a combination of theory and known physics that might approximate initial conditions, the simulations recreate the subsequent processes that

would have led to the current structure. By comparing the properties of the simulated universe and galaxies to observations the validity of the underlying cosmological model can be tested.

This tool has allowed Hernquist and Springel, either individually or collaboratively, to show that information from the cosmic microwave background (the relic radiation from the Big Bang) and light spectra from quasars are reliable predictors of present-day galactic structures. They have also used computational simulations to test theories relating to cold dark matter (the invisible matter that comprises roughly four-fifths of the universe's matter) and dark energy (a mysterious force causing an accelerated late-time expansion of the universe), and how they in concert with ordinary baryons give rise to today's visible structures.

In addition to their own discoveries, Hernquist and Springel have provided the means for other researchers to transform cosmology. For instance, Hernquist, Springel and their collaborators have emphasized the need for simulations to incorporate feedback—the portion of the outflow of material (such as gas) that feeds back into evolutionary processes. In 2005, working with a collaborator (Tiziana Di Matteo), they demonstrated that black-hole feedback determines the growth relationship between supermassive black holes and their host galaxies.

Thanks to their example, feedback is now a standard component of cosmological simulations at virtually every scale, from stellar evolution, protoplanetary disks, supermassive black holes, gas physics in galaxies and galaxy mergers, to dark matter physics that determines the distribution of superclusters of galaxies into web-like tendrils.

Hernquist and Springel have also written several codes that cosmologists consider indispensable. Hernquist (along with Neal Katz) created TreeSPH, which Hernquist and, subsequently, other researchers used to investigate large-scale structures. Springel wrote two codes that today dominate cosmological research. In 2001 he (with Naoki Yoshida and Simon White) introduced GADGET, which he used in creating the Millennium Simulation, the first dark-matter-only simulation to encompass a representative volume of the universe. The resulting series of images provided a vivid and compelling set of images that helped popularize the idea of a “cosmic web.” Springel also led the creation of AREPO, a moving mesh simulation code which he and Hernquist (and a team of collaborators) subsequently used in the creation of Illustris, a 2014 simulation of the formation of the galaxy distribution across a broad area of the universe.

The problems of cosmic structure formation and the formation and evolution of galaxies are extremely complex, so much so that numerical simulations are the only practical way at present to construct a full theoretical model. The remarkable success of contemporary models such as Illustris, which can reproduce properties of the universe from its largest structures to individual galaxies, over nearly the full history of cosmic time, is the result of a triumphal marriage between state-of-the-art computation and deep astrophysical insights. This year's Gruber Cosmology Prize recognizes the leading role in this breakthrough played by Lars Hernquist and Volker Springel.

Additional Information

In addition to the cash award, each recipient will receive a gold laureate pin and a citation that reads:

The Gruber Foundation is pleased to present the 2020 Cosmology Prize to Lars Hernquist and Volker Springel for their transformative work on structure formation in the universe, and development of numerical algorithms and community codes further used by many other researchers to significantly advance the field. The contributions of Hernquist and Springel have led to profound insights spanning billions of years of cosmic evolution, including simulations of the growth of early density fluctuations through to present-day galaxies, the influence of galaxy mergers on star formation, and the close coevolution of supermassive black holes with their host galaxies.

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The Cosmology Prize honors a leading cosmologist, astronomer, astrophysicist or scientific philosopher for theoretical, analytical, conceptual or observational discoveries leading to fundamental advances in our understanding of the universe.

Laureates of the Gruber Cosmology Prize:

- **2019: Nicholas Kaiser and Joseph Silk**, revolutionized cosmology with contributions to two of its vital components: dark matter and relic radiation from the Big Bang
- **2018: The Planck Team, Jean-Loup Puget and Nazzareno Mandolesi**, for measuring the universe's contents and the geometry and test inflation with unparalleled precision
- **2017: Sandra M. Faber**, for a body of work that has helped establish many of the foundational principles underlying the modern understanding of the universe on the largest scales
- **2016: Rainer Weiss, Kip Thorne, Ronald Drever**, and the entire **LIGO team**, for a first detection of gravitational waves that emanated from the collision of two black holes
- **2015: John Carlstrom, Jeremiah Ostriker, and Lyman Page**, for their individual and collective contributions to the study of the universe on the largest scales
- **2014: Jaan Einasto, Kenneth Freeman, Brent Tully and Sidney van den Bergh**, for pioneering contributions to the understanding of the structure and composition of the nearby Universe
- **2013: Viatcheslav Mukhanov and Alexei Starobinsky**, for contributions to inflationary cosmology and the theory of inflationary perturbations of the metric, which changed our views on the origin of our universe and on the mechanism of formation of its structure
- **2012: Charles Bennett and the WMAP Team**, for their exquisite measurements of anisotropies in the relic radiation from the Big Bang---the Cosmic Microwave Background
- **2011: Marc Davis, George Efstathiou, Carlos Frenk, Simon White**, pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the Universe
- **2010: Charles Steidel**, for his groundbreaking studies of the distant Universe
- **2009: Wendy Freedman, Robert Kennicutt and Jeremy Mould**, for the definitive measurement of the rate of expansion of the universe, Hubble's Constant
- **2008: J. Richard Bond**, for his pioneering contributions to our understanding of the development of structures in the universe
- **2007: Saul Perlmutter and Brian Schmidt** and their teams: the **Supernova Cosmology Project** and the **High-z Supernova Search Team**, for independently discovering that the expansion of the universe is accelerating

- **2006: John Mather** and the **Cosmic Background Explorer (COBE) Team**, for studies confirming that our universe was born in a hot Big Bang
- **2005: James E. Gunn**, for leading the design of a silicon-based camera for the Hubble Space Telescope and developing the original concept for the Sloan Digital Sky Survey
- **2004: Alan Guth** and **Andrei Linde**, for their roles in developing and refining the theory of cosmic inflation
- **2003: Rashid Alievich Sunyaev**, for his pioneering work on the nature of the cosmic microwave background and its interaction with intervening matter
- **2002: Vera Rubin**, for discovering that much of the universe is unseen black matter, through her studies of the rotation of spiral galaxies
- **2001: Martin Rees**, for his extraordinary intuition in unraveling the complexities of the universe
- **2000: Allan R. Sandage** and **Phillip J. E. (Jim) Peebles**, Sandage for pursuing the true values of the Hubble constant, the deceleration parameter and the age of the universe; Peebles for advancing our understanding of how energy and matter formed the rich patterns of galaxies observed today

The Prize recipients are chosen by the Cosmology Selection Advisory Board. Its members are:

James Evans, University of Puget Sound; **Paul Ho**, Institute of Astronomy and Astrophysics, Academia Sinica; **Robert Kennicutt**, University of Arizona (Chair); **Frans Pretorius**, Princeton University; **Angela Olinto**, The University of Chicago; **Jean-Loup Puget**, The National Centre for Scientific Research (CNRS); **Linda Tacconi**, Max Planck Institute for Extraterrestrial Physics. **Wendy Freedman** of The University of Chicago and **Martin Rees** of The University of Cambridge also serve as special Cosmology advisors to the Foundation.

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The Gruber International Prize Program honors individuals in the fields of Cosmology, Genetics and Neuroscience, whose groundbreaking work provides new models that inspire and enable fundamental shifts in knowledge and culture. The Selection Advisory Boards choose individuals whose contributions in their respective fields advance our knowledge and potentially have a profound impact on our lives.

The Gruber Foundation was established in 1993 by the late Peter Gruber and his wife Patricia Gruber. The Foundation began its International Prize Program in 2000, with the inaugural Cosmology Prize.

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For more information on the Gruber Prizes, visit www.gruber.yale.edu, e-mail info@gruber.yale.edu or contact A. Sarah Hreha at +1 (203) 432-6231. By mail: The Gruber Foundation, Yale University, Office of Development, PO Box 2038, New Haven, CT 06521.

Media materials and additional background information on the Gruber Prizes are in our online newsroom: <https://gruber.yale.edu/news-media>

*Lars Hernquist Photo Credit: Dr. Anna N. Zytkov