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Marc Kamionkowski, Uroš Seljak, and Matias Zaldarriaga Receive \$500,000 Gruber Cosmology Prize



Marc Kamionkowski



Uroš Seljak



Matias Zaldarriaga

May 5, 2021, New Haven, CT — The 2021 Gruber Cosmology Prize recognizes Marc Kamionkowski, Johns Hopkins University, Uroš Seljak, University of California at Berkeley and Lawrence Berkeley National Laboratory, and Matias Zaldarriaga, Institute for Advanced Study, for their contributions to methods essential for studying the early universe.

Kamionkowski, Seljak, and Zaldarriaga will equally share the \$500,000 award, and each will receive a gold medal at a ceremony that will take place in August at the 24th International Conference on Particle Physics and Cosmology (COSMO'21) conference series at the University of Illinois and online. The citation honors contributions to cosmology that “have been essential to the development of this field of research over the last twenty-five years.”

Many of the techniques developed by these three physicists focus on the cosmic microwave background (CMB), the relic radiation that dates to the era of decoupling—when atoms and radiation emerged from the developing universe’s primordial plasma and went their separate ways. The atoms remain in the form of the matter in the universe, and the radiation remains in the form of a background “noise” that pervades space in every direction, providing an image of the universe when it was only 379,000 years old. That same “baby picture” of the universe, however, serves as an observational limit.

As a key part of this work, Kamionkowski and, independently but simultaneously, Seljak and Zaldarriaga found a mathematical means to use the radiation from the CMB to infer what’s on the other side, all the way back to the first fraction of a fraction of a second of the universe’s existence. That method is

polarization—the degree to which an oscillating wave, bouncing up and down relative to the direction of travel, diverges from a strictly perpendicular orientation.

The two papers appeared side by side in *Physical Review Letters* in 1997. (Kamionkowski shared authorship with Albert Stebbins, Fermilab, and Arthur Kosowsky, University of Pittsburgh.) The impact of the papers was seismic, the reverberations enduring.

By observing polarization in the CMB, cosmologists can match theoretical predictions of early-universe properties using data that would otherwise be inaccessible. Among the observatories that have used polarization to make those measurements are the WMAP and Planck satellites (whose principal investigators and teams received the Gruber Cosmology Prize in 2012 and 2018, respectively). Those measurements have allowed cosmologists to determine that the universe is 13.8 billion years old and comprises roughly 5 percent ordinary matter, 26 percent dark matter, and 69 percent dark energy.

Yet as powerful as polarization has proven to be in probing the early universe, it is now inspiring a new generation of research programs that will detect—or not—the final piece in that reigning cosmological model: inflation, a theoretical moment at the very beginning of the universe’s existence when space would have undergone an expansion of almost unfathomable proportions. (The theorists who independently created that idea, Alan Guth and Andrei Linde, received the 2004 Gruber Cosmology Prize.) The two 1997 papers by Kamionkowski, Seljak and Zaldarriaga identified a signature in the CMB polarization that would render a verdict on the existence of primordial gravitational waves—a key prediction of inflationary theory.

Although the 1997 papers are two of the seminal works by Kamionkowski, Seljak, and Zaldarriaga, the 2021 Gruber Prize also recognizes their career-long contributions to cosmology.

Even before writing their own 1997 paper, Seljak and Zaldarriaga had already created a code that made the study of certain aspects of the CMB thousands of times faster—in fact, they named it CMBfast. And because they made the code available for free it dominated CMB research for years to come. (Today it endures as the foundation for every code analyzing CMB polarization.) Over the decades, singly and together, they have continued to perform influential mathematical analyses and to create new theoretical interpretations in such areas as inflation, gravitational waves, and the use of general relativistic effects (weak lensing) on light from distant sources to infer the characteristics of the dark matter in individual galaxy halos as well as in the large-scale structure of galactic formation.

Kamionkowski is also well known for his work on cosmological-parameter determination and parity-breaking effects in the CMB, and he has similarly over the years made important subsequent contributions to the study of CMB polarization. He also has significant work in multiple other areas of cosmology, including dark matter, inflation, the acceleration of the expansion of the universe, cosmic phase transitions, and gravitational waves.

As for those two 1997 papers: In the words of one nominator to this year’s Gruber Prize, “The significance of this work for cosmology cannot be overstated.”

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 2021 Cosmology Prize to Marc Kamionkowski, Uroš Seljak, and Matias Zaldarriaga for their work on the Cosmic Microwave Background, the most direct tracer of the primordial universe and of its physics. Their theoretical predictions and analysis tools for the cosmic background, its intensity, and even more its polarization, have been essential to the development of this field of research over the last twenty-five years, already testing predictions of the inflation model for the early expansion of our universe. Furthermore, their work has been key to initiating new observation projects extending over the next fifteen years, in the quest for detecting the imprint of primordial gravitational waves on the microwave background.

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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:

- **2020: Lars Hernquist and Volker Springel**, for computer simulations that revolutionized the study of processes behind the structure of the cosmos
- **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 International Astronomical Union partners with the Foundation on the Prize and nominates the members of the Selection Advisory Board that chooses the Prize recipients. Its members are:

James Evans, University of Puget Sound; **Paul Ho**, Institute of Astronomy and Astrophysics, Academia Sinica; **Robert Kennicutt**, University of Arizona (Chair); **Angela Olinto**, The University of Chicago; **Jean-Loup Puget**, The National Centre for Scientific Research (CNRS); **Hans Ringström**, KTH Royal Institute of Technology; **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>