

Understanding Dark Energy and Neutrinos from the South Pole

Miller Fellow Focus: Tijmen de Haan

Modern cosmology provides an incredibly powerful description of the universe we live in. The standard model of Big Bang cosmology takes only a few assumptions about the physical laws and initial conditions, and makes a wealth of predictions. As our techniques for measuring the large-scale properties of the universe improve, the observations are found to be consistent with the predictions of the standard model of Big Bang cosmology time and time again. However, several open questions remain.

In the late 1990s, we learned that the expansion of the universe is currently accelerating. This is due to a mysterious type of energy cosmologists have termed dark energy. This discovery led to the 2011 Nobel Prize in Physics being awarded to Saul Perlmutter (Senior Miller Fellow 2010-2015), Brian Schmidt, and Adam Riess (Miller Fellow 1996-1998). Much remains to be learned about this enigmatic form of energy. For instance, has its energy density evolved with cosmic time, or is it constant, perhaps implying that dark energy is a property of space itself?



We can also use our measurements of the expansion rate and growth of structure in the universe to determine the properties of its contents. Around the turn of the millenium, neutrinos, long thought to be massless particles, were found to carry a small amount of mass. However, measuring this mass in the laboratory remains very difficult. Neutrinos make up about a part in a thousand of the total energy density of the universe, and leave a characteristic signature in the combination of the expansion rate and growth of structure in the universe. Therefore, sufficiently precise cosmological observations could provide a measurement of the total neutrino mass. In fact, the

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Call for Nominations:

Miller Research Fellowship Nominations

Deadline: Saturday, September 10, 2016

Miller Research Professorship Applications

Deadline: Thursday, September 15, 2016

Visiting Miller Professorship Departmental Nominations

Deadline: Friday, September 16, 2016

See page 5 for more details.

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miller.berkeley.edu

"In the Spring of 2000, I was awarded a Miller Research Professorship. With this time off from teaching and committees, I decided to spend a week amusing myself by trying to understand this immunology paper. Thus began my work at the intersection of statistical physics and immunology, which has been, and continues to be, most satisfying. The time and freedom provided by the Miller Professorship was invaluable for my transition to immunology, and so I am very grateful to the Miller Institute."

Arup Chakraborty
Robert T. Haslam Professor of Chemical Engineering,
Professor of Chemistry, Professor of Physics, Professor of
Biological Engineering, MIT, Miller Professor 2000



next generation of cosmological probes are currently nearly guaranteed to make this measurement successfully, regardless of what the total neutrino mass is, decades before such a result would be available through laboratory measurements.

These dark energy and neutrino questions can be probed by several classes of cosmological observations. I specialize in the study of galaxy clusters. Agglomerations of hundreds of galaxies in a region a few million light-years across, galaxy clusters are the most massive gravitationally collapsed objects in the universe, weighing up to 10^{15} times the mass of the sun. **Figure 1** shows an example of a very massive galaxy cluster, discovered in South Pole Telescope data. Given a cosmological model, the abundance of galaxy clusters is robustly predicted by cosmological simulations. We can therefore use measurements of galaxy cluster abundance, as a function of their mass and cosmic distance, to make inferences about cosmology, such as the dark energy and neutrino questions posed above.

Built in the 2006-2007 austral summer, the 10-m South Pole Telescope (**Figure 2**) is a millimeter-wave telescope located at the geographic South Pole. One of its primary missions is to use the cosmic microwave background, the leftover light from the Big Bang, as a backlight to the universe. When that 13 billion year-old light travels through a galaxy cluster, some of it is scattered, leaving a characteristic (though tiny) imprint in the cosmic microwave background, one which we use to survey for galaxy clusters. Uniquely, this technique provides a mass-limited sample of galaxy clusters, independent of their distance from us.

Earlier this year, we completed an analysis of a sample of several hundred galaxy clusters from the 2500 square degree South Pole Telescope survey, which was taken from 2007 to 2011. The main challenge was to accurately determine the average mass of the galaxy clusters. This was accomplished using a large collection of X-ray, optical, and infrared data, yielding some of the most powerful cosmological constraints from galaxy cluster abundance measurements to date.

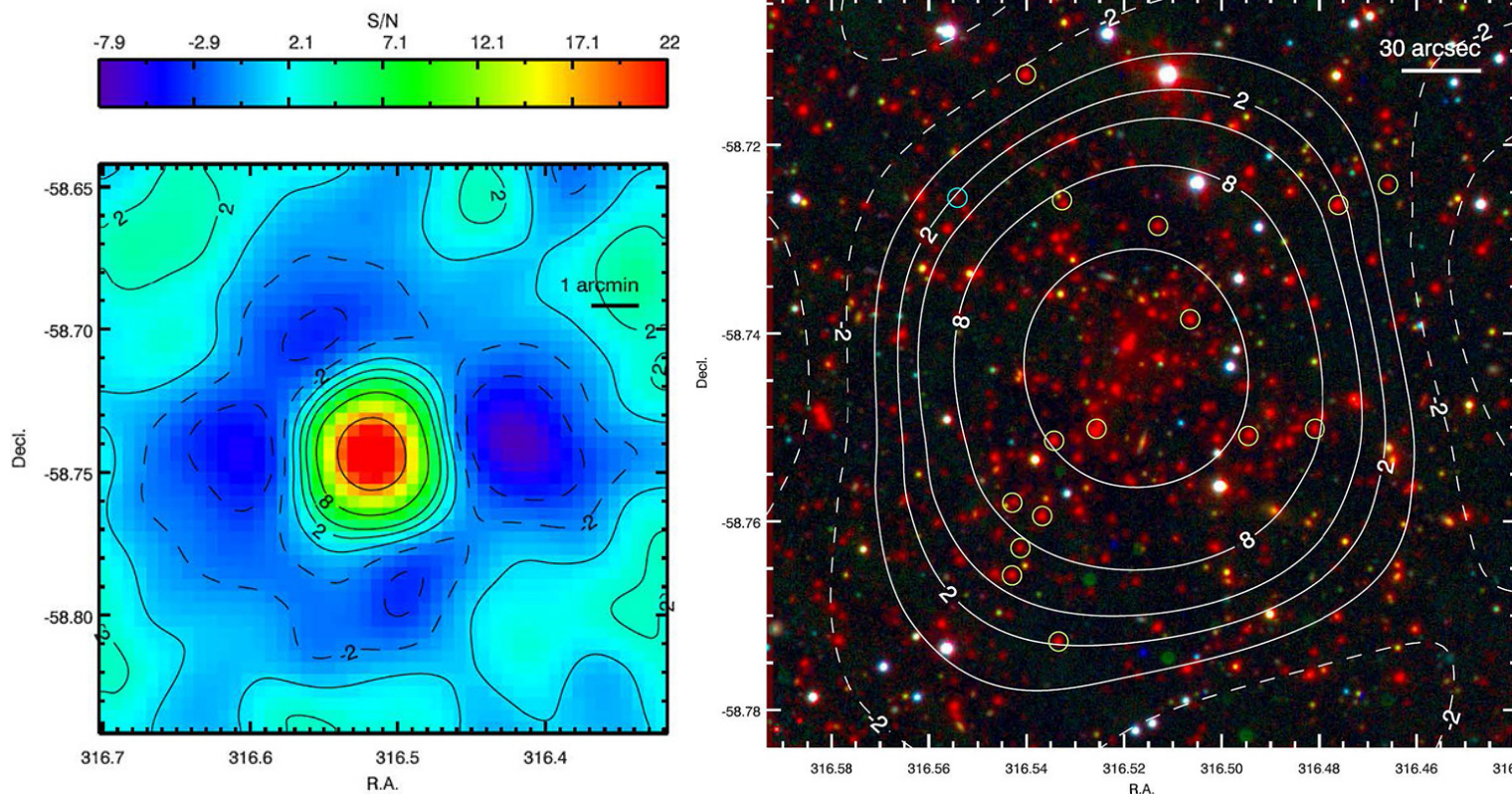


Figure 1: One of the galaxy clusters discovered in the South Pole Telescope survey. The map on the left shows the South Pole Telescope data, while the image on the right shows an optical/infrared image, revealing many of the member galaxies. The South Pole Telescope significance contours are overlaid in both panels. This galaxy cluster, SPT-CL J2106-5844, is currently the most massive known galaxy cluster from before the scale factor of the universe was half its present value.

During the coming austral summer (November 2016-February 2017), we will be installing the third-generation camera on the South Pole Telescope, which will provide a ten-fold improvement in the speed at which we can map the sky at mm-wavelengths. This improvement was made possible due to several advances in technology, including multi-chroics (where multiple wavelengths are observed simultaneously in one pixel), an improved optics design, and improved detector readout technology. The exquisite sensitivity of the third-generation South Pole Telescope survey should not only allow us to discover thousands of new galaxy clusters, but also make the most precise measurement of the average galaxy cluster mass in that sample, drastically improving the cosmological power of the galaxy cluster abundance measurement and thereby our understanding of key cosmological questions.



Figure 2. The 10-m South Pole Telescope observing during the austral winter. The Milky Way and an aurora can be seen in the background. Photo credit: Nicholas Huang

Although the standard model of Big Bang cosmology has been immensely successful, many questions remain to be answered in cosmology. What is the nature of dark energy: the mysterious form of energy that is likely to determine the ultimate fate of the universe? What can we learn about neutrinos using cosmology? Using the South Pole Telescope, we have already improved our knowledge of such questions by measuring the abundance of galaxy clusters. The upcoming third-generation camera will map the sky at ten times the rate of the current instrument and could provide key insights into these questions.

Having grown up in the Netherlands, Tijmen de Haan (Miller Fellow 2014-2017) obtained his Ph.D. in Physics from McGill University. He has spent several austral summer seasons deploying instrumentation upgrades at the South Pole. When not building instruments in the lab or analyzing telescope data, Tijmen enjoys cooking, cycling, and playing the piano.

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From the Executive Director



Jasper Rine

Executive Director of the Miller Institute & Professor of Genetics and Developmental Biology

To a first approximation, the Miller Institute and I are about the same age, having left our 60th anniversaries astern, or in the rear view mirror, whichever metaphor best captures your imagination. Fortunately, at least one of us shows only improvement with age.

The 60th Anniversary Symposium, and related activities were among the scientific highlights of the campus this past year. At the symposium

we learned how you can tell a fossil fish from a fossil marine mammal and why, how form and function in biology has a discernable mathematical foundation, how biological molecules dance about once made and finally settle into their final ensemble of structures, and when and where earthquakes are so deadly, and where they are not.

As befits an individual or organization entering its seventh decade, it is time to take stock and see if we have been true to the original vision of the institute and whether any corrections might be needed. I wish Mary and Adolph Sprague Miller were alive to witness into what their contribution has blossomed. From an endowment back in the early 1940s that would have kept one modern research lab in business only long enough to produce a few Ph.D.s, we now have one of the most significant institutions in the nation in terms of producing world-class scholars across all scientific disciplines. The institute provides generous support for 30 postdoctoral fellows at any given time, each a leader in his/her field. The institute also supports multiple Visiting Miller Professors and domestic Miller Professors through a new, more flexible structure that matches the differences between the cultures of different fields. Each contributes to the richness of the scientific enterprise of Berkeley.

The pace of scientific advances continues to accelerate, and the fall and spring Miller Institute dinners provide unique windows into exciting developments. Last fall, Rasmus Nielsen taught us about how exploration of human genomes has revealed aspects of our collective past, showing that those with European and Asian Ancestry have bits of the Neanderthal genome left as molecular fossils of past interbreeding with our hominid ancestors. At the spring dinner we saw into the future as Jennifer Doudna described her amazing work with the Cas9 nuclease and its power for editing genomes. Her work enables genes in essentially any organism to be changed in any way to test specific ideas about biology. Cas9 has obvious importance in treating human disease. Of course, it also raises important issues regarding bioethics that we will continue to grapple with in the coming years.

The Spring Symposium, a 20 year tradition started and sustained by the Miller Institute's own Senior Fellow, Raymond Jeanloz, brought in 7 world leaders to the Marconi Center on Tomales Bay to give us all a close-up look at different facets of science, as described by leading practitioners of their discipline. Work has already begun on assembling the program for next spring's symposium. It's too early to tell what the topics will be, but we have everything from LIGO's detection of gravity waves, to quantum weirdness, to yeast that produce opioids, to a new species in the human lineage, and more, to choose from.

Michael Manga has taken over as the faculty leader of the Spring Symposium Selection Committee, as his term on the Executive Committee came to an end. We thank Raymond for the magnificent job he did over the past two decades, and will continue to rely upon his advice in the coming years. Roland Burgmann from Earth and Planetary Science is a new member of the Executive Committee, replacing Michael. We welcome the return of Craig Evans to the Executive Committee following his service as interim chair of the Math Department.

There have been a few changes in our Advisory Board over the last year. A few months ago, we learned the sad news that our former Advisor, Sir Harry Kroto, passed away. We will miss his sharp insights and passion for science and science education. Our colleague Vaughan Jones, currently from Vanderbilt University, has concluded his service with the Institute. We have valued his contributions to our decision making processes over the years. We are fortunate to have Yun Song from the University of Pennsylvania join our Advisory Board for the coming year. The staff support for the Institute is second to none. At many institutions, the position of postdoctoral fellows can be rather isolating, with no formal way of making connections beyond a sponsor's laboratory. The rapport between Kathy Day and her staff and the fellows and faculty let the scientists affiliated with the institute be part of a bigger community that transcends typical departmental boundaries.

These are challenging years for all academic institutions, Berkeley included, as the strain on the traditional business model or research institutions reaches new heights. The Miller Institute remains true to its original mission. We have one core mission: to enable the best and the brightest of all fields of science to achieve their potential while contributing to the rich scientific environment of Berkeley. Our alumni make up a substantial fraction of the faculty of the world's leading research universities.

Emeritus Miller Institute Members!

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Call For Nominations: Miller Research Competitions

Miller Research Fellowship 2017-2020

Online Nomination Deadline: Saturday, Sept. 10, 2016

The Miller Institute for Basic Research in Science invites department chairs, faculty advisors, professors and research scientists at institutions around the world to submit online nominations for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. Miller Fellows also have a keen curiosity about all science and share an appreciation for an interdisciplinary experience. The Miller Institute is the sponsor and the administrative home department for each Miller Fellow who is hosted by an academic department on the Berkeley campus. All research is performed in the facilities provided by the host UC Berkeley academic department(s). A list of current and former Miller Research Fellows is available on our website.

Miller Research Fellowships are intended for exceptional young scientists of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. Normally, Miller Fellows are expected to begin their Fellowship shortly after being awarded their Ph.D. Applicants who have already completed substantial postdoctoral training are unlikely to be successful except in unusual circumstances. **A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle.** Nominees who are non-US citizens must be eligible for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. The Miller Institute does not support H1B visa status. The Fellowship term must commence between July 1 and September 1, 2017. Eligible nominees will be invited by the Institute to apply for the Fellowship. Direct applications and self-nominations are not accepted.

*All nominations must be submitted using the Online Nomination System at: <http://miller.berkeley.edu>

Nominators will need the following required information to complete the online nomination process:

- + Nominee's complete **full and legal name** (do not use nicknames)
- + Nominee's current institution
- + Nominee's complete, current, and active E-mail address, current mailing address with postal code and telephone number
- + Nominee's Ph.D. Institution and (expected) Date of Ph.D. (month & year required)
- + Letter of recommendation and judgment of nominee's promise by the nominator. Letter must be specific to the Miller Fellowship, have a current date, and be on institutional letterhead. The Executive Committee finds it helpful in the recommendation letter to have the candidate compared with others at a similar stage in their development.
- + Nominator's current active E-mail address, title, and professional mailing address (include zip code/campus mail code)

The Institute provides a stipend of \$65,000 with annual increases on subsequent anniversary dates and an annual research fund of \$10,000, for total initial compensation of \$75,000. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of \$3,000 for moving personal belongings. Benefits, including medical, dental, vision and life insurance are provided with a modest contribution from the Miller Fellow. All University of California postdocs are represented by the UAW. Fellowships are awarded for three years, generally beginning August 1, 2017 and ending July 31, 2020. Approximately eight to ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

Nomination & Application details: miller.berkeley.edu

Questions? Kathryn Day: 510-642-4088 | millerinstitute@berkeley.edu

Miller Research Professorship 2017

Online Application Deadline: Thursday, Sept. 15, 2016

The Miller Professorship program is looking with a view to the future in announcing the call for applications for terms in 2017-2018. The goal is to accommodate a greater range of Berkeley campus faculty to participate in the vibrant Miller community. The objective of the Miller Professorship program is to provide opportunities for faculty to pursue new research directions on the Berkeley campus. For some, this may best be enabled by taking time off from teaching. This will continue to be an option. For others, the teaching obligations are critical to maintaining campus academic programs. Thus be an option for Miller Professors to continue campus service and teaching. Funds will be distributed differently depending upon the choice selected. Details of the terms and the application procedure are posted on the Miller Institute website. The primary purpose of the Miller Professorship program and the evaluation criteria will continue to be research excellence. Applicants will also be encouraged to describe their interest in participating in the Miller Institute community.

Applications from UC Berkeley faculty for Miller Research Professorship terms in the 2017-18 academic year are being accepted online now. Appointees are encouraged to follow promising leads that may develop in the course of their research.

Applications are judged competitively and are due by Thursday, September 15, 2016. It is anticipated that between five to eight awards will be made.

Visiting Miller Research Professorship AY 2017

Online Nomination Deadline: Friday, Sept. 16, 2016

The Advisory Board of the Miller Institute for Basic Research in Science invites Berkeley faculty to submit online nominations for Visiting Miller Research Professorships and the Gabor A. and Judith K. Somorjai Visiting Miller Professorship Award for terms in Fall 2017 or Spring 2018. The purpose of these Visiting Miller Professorships is to bring promising or eminent scientists to the Berkeley campus on a short-term basis for collaborative research interactions. It is required that awardees are in residence at Berkeley during their appointment term. Faculty members or research scientists from any place in the world are eligible to be considered for sponsorship. Non-US citizens must be eligible for J-1 Scholar visa status. Faculty members at other UC campuses are eligible to be nominated for this program. The Miller Institute, as the sponsor and administrative department, will extend the invitation to the nominee after advising the nominator of its selection.

MILLER INSTITUTE FOR BASIC RESEARCH IN SCIENCE

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In the News

Alejandro Rico Guevara (incoming Miller Fellow 2017-2020) received the **Pitelka Award for Excellence in Research** from the International Society for Behavioral Ecology.

N. Louise Glass (Miller Professor 2011 - 2012) has accepted the position of **Director of the Environmental Genomics and Systems Biology Division** at the Lawrence Berkeley National Lab.

Steven Lindow (Miller Professor 2010) has been selected to receive the **Award of Distinction**, the highest award made by the American Phytopathological Society in honor of his significant contributions to the science of plant pathology.

Stephen Leone (Visiting Miller Professor 1990, Miller Professor 2010, Advisory Board Member 2015 - Current) has received an **Honorary DSc Degree from the University of Warwick**.

Mikhail Shapiro (Miller Fellow 2011 - 2013) is among 37 promising scientists who have received research awards from the **Pew Charitable Trusts** to pursue research in cell biology, neuroscience and cancer.

Marius Crainic (Miller Fellow 2001 - 2002) and **Shrinivas Kulkarni** (Visiting Miller Professor 1995) are among 16 prominent researchers appointed as new members of the **Royal Netherlands Academy of Arts and Sciences**.

Eliezer Rabinovici (Visiting Miller Professor 2002) has been elected as **Vice-President of the Council of the European Organization for Nuclear Research (CERN)**, the highest authority of the organization.

Greg Bowman (Miller Fellow 2011 - 2014) received a new five year **grant award** from the National Science Foundation for his research entitled "CAREER: FAST methods for protein folding and design."

Julian Shun (Miller Fellow 2015 - 2018) has won the **2015 ACM Doctoral Dissertation Award** for "Shared-Memory Parallelism Can Be Simple, Fast, and Scalable." This award is presented annually to the author of the best doctoral dissertation in computer science and engineering.

NAS announced new members:
Ian Agol (Miller Professor 2012)
Roberto Car (Visiting Miller Professor 1994)
Arup Chakraborty (Miller Professor 2000)
Steven Evans (Miller Professor 2002 - 2003)
Marsha Lester (Visiting Miller Professor 2003)
Susan Marqusee (Miller Professor 2016 - 2017)
Peidong Yang (Miller Professor 2009)
Yuval Peres (Miller Professor 2002 - 2003)

Richard Henderson (Visiting Miller Professor 1993) has received the **NAS Alexander Hollaender Award in Biophysics** in recognition of his extraordinary scientific achievement.

Gil Navon (Visiting Miller Professor 1997) was awarded the **Gold Medal** from the International Society of Magnetic Resonance in Medicine (ISMRM).

AAAS announced new members:
Donna Blackmond (Visiting Miller Professor 2003)
Joel Kingsolver (Miller Fellow 1981 - 1983)
Sarah Otto (Miller Fellow 1992 - 1994)

Marc Kamionkowski (Visiting Miller Professor 2010) was elected a **2016 Fellow of the International Society of General Relativity and Gravitation** "for his contributions to contemporary cosmology and general relativity, particularly the development of the theoretical foundation for the detection of relic gravitational waves from inflation in the Cosmic Microwave Background polarization."

Guggenheim Fellows named:
Feryal Özel (Visiting Miller Professor 2014)
Chris Fromme (Miller Fellow 2004 - 2007)

Three former Visiting Miller Professors are among 50 leading scientists elected as **Fellows of The Royal Society**:
Steven Balbus (Visiting Miller Professor 2012)
Lakshminarayanan Mahadevan (Visiting Miller Professor 2006)
Svante Paabo (Visiting Miller Professor 2013)

We welcome news contributions from our former members. Please email news to: miller_adm@berkeley.edu

We've Moved!



New Address:
2538 Channing Way, D-104
Berkeley, CA 94720-5190

More News...

For updated news: miller.berkeley.edu/news



20th Annual Interdisciplinary Symposium



Miller Fellow Alums Return!



Miller Fellow Norm Yao and Speaker Eddie Farhi



Miller Fellow Simone Ferraro with former Miller Fellow Francesco D'Eramo



Lee Billings, Scientific America with Miller Fellow Rachel Zucker



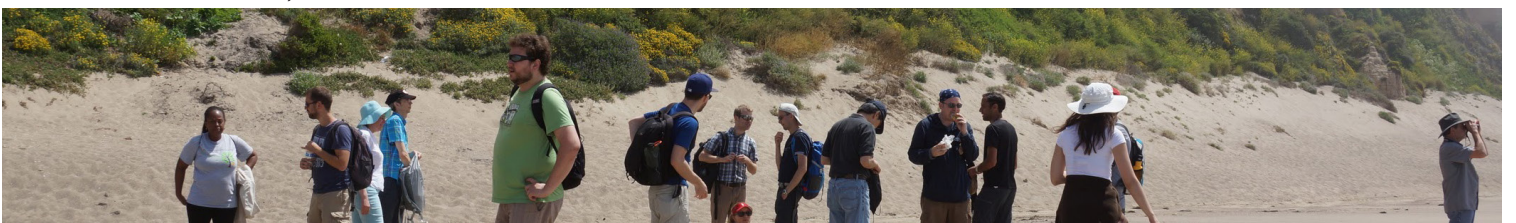
Speakers: Jordan Ellenberg, John Boothroyd & Percy Liang



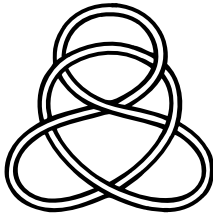
Peter Hintz, Jordan Ellenberg, Ryan Trainor, Carson Bruns, Sebastian Hoenna & Raymond Jeanloz



Speakers: Mark Cane, Eddi Farhi, Pupa Gilbert & Heather Knutson



Pre-Symposium hike



Non-Profit
Organization
U.S. Postage
PAID
University of
California,
Berkeley

University of California, Berkeley

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Miller Institute News - Fall 2016
Please send address corrections to:
miller_adm@berkeley.edu

Birth Announcements

Alejandro Rico Guevara (incoming Miller Fellow 2017-2020) & his wife, Kristiina Hurme announced the birth of their daughter, Sierra Analeema Rico Hurme, born June 17, 2016.

Amy Shyer (Miller Fellow 2013-2015) & her husband, Alan Rodrigues announced the birth of their son, Marlowe Vaughn Rodrigues, born May 13, 2016.

Next Steps

The Miller Institute congratulates the Miller Fellows on their next endeavors:

- Brooke Gardner** (Postdoc @ A. Martin lab, UC Berkeley)
- Sung-Jin Oh** (CMC Research Professor @ Korean Institute of Advanced Studies)
- Ashivni Shekhawat** (Data Scientist @ Lyft)
- Blake Sherwin** (Postdoc @ Lawrence Berkeley National Lab)
- Amy Shyer** (Postdoc @ R. Harland lab, UC Berkeley)

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The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."

For More Information:

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+ 510.642.4088 | miller.berkeley.edu