The Adolph C. and Mary Sprague

Miller Institute
for Basic Research in Science

Newsletter
Spring 2018

Earth's Dynamic Past Environments

Miller Fellow Focus: Sarah Slotznick

What makes a planet habitable for complex life? This question is central to many planetary exploration programs—looking for signs of ancient or extant extraterrestrial life or speculating on future colonization. We have one exceptional case-study for understanding this and other fundamental questions about the origin and evolution of llife—planet Earth and its dynamic physical, chemical, and biological evolution.

A major research focus in early Earth History has been understanding past oxygen levels due to their importance for biogeochemical processes. Although life can exist without oxygen, eukaryotes (the domain of life that contains all macroscopic life forms) are thought to require oxygen based on: (1) current understanding of eukaryotic evolutionary trees, (2) the fact that most eukaryotes today are aerobic, and (3) the necessity for oxygen in making certain biological compounds (e.g. sterols) contained in eukaryotes. Earth did not always have appreciable oxygen in its atmosphere; the first signs of atmospheric oxygen are found 2.3 billion years ago. The levels of atmospheric oxygen in the time following its initial appearance are poorly constrained, and it is unknown when oxygen rose to its current levels **(Figure 1)**. Understanding the environmental conditions of the early Earth provides essential constraints on the timing and pacing of evolution and how it might have been aided, frustrated, or unaffected by changing environmental conditions.

There is no simple record of oxygen levels of the ancient Earth; instead scientists turn to proxies based on the geological record. Elements sensitive to reduction and oxidation (redox) processes on Earth's surface have been a major target for understanding past environmental conditions. In particular, observations of changes in iron chemistry and mineralogy in different rocks over time have been utilized for over 50 years to understand changes in Earth's environmental conditions. For example, minerals with reduced iron were common as transported particles prior to 2.3 billion years ago, whereas afterwards these grains were not preserved in surface environments and minerals with oxidized iron dominate shallow water sediments. Modeling of the chemical reaction rates, weathering, and transport processes of these detrital iron minerals can constrain a lower limit for oxygen (e.g. **Figure 1**).

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Deadline: September 10, 2018

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For more information on all our programs online: miller.berkeley.edu & on PAGES 2 & 3.

"The unique setup of the Miller Institute allows for that rarest of academic phenomena: deep interdisciplinary dialogue. Everything about the Miller experience is set up to foster appreciation, idea cross-fertilization, and collaboration between different fields."

- Milo Lin
Miller Fellow 2012-2015,
Assistant Professor, Systems Biology, Biophysics
University of Texas
Southwestern Medical Center.

Call for Miller Professor Applications

Online Application Deadline: Thursday, September 13, 2018

Miller Research Professorship AY 2019-2020

The Miller Professorship program is looking with a view to the future in announcing the call for applications for terms in 2019-2020. The goal is to accommodate a greater range of 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 continues to be an option. For others, the teaching obligations are critical to maintaining campus academic programs. There is thus a second option for Miller Professors, allowing the continuation of 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. Proposals to write books are not viewed as competitive. Applicants are encouraged to describe their interest in participating in the Miller Institute community.

Beginning May 2018 applications will be accepted from UC Berkeley faculty only for terms in the 2019-2020 academic year. The purpose of the Professorship is to allow members of the faculty to pursue new research directions on the Berkeley campus. Appointees are encouraged to follow promising leads that may develop in the course of their research.

Applications are judged competitively and are due by September 13, 2018. It is anticipated that between five to eight awards will be made.

Call for Visiting Miller Professor Nominations

Online Nomination Deadline: Friday, September 14, 2018

Visiting Miller Research Professorship AY 2019-2020

The Advisory Board of the Miller Institute for Basic Research in Science invites Berkeley faculty to submit online departmental nominations for Visiting Miller Research Professorships and the Gabor A. and Judith K. Somorjai Visiting Miller Professorship Award for terms in Fall 2019 or Spring 2020. 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 an invitation after advising the department of its selection.

Any questions regarding this program may be directed to the Institute's office by phone at (510) 642-4088 or by emailing the Miller Institute.

:: **Nomination & Application details**: miller.berkeley.edu

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

Call for Nominations: Miller Research Fellowship

2019-2022 Term

Nomination Deadline: September 10, 2018

The Miller Institute for Basic Research in Science invites department chairs, faculty advisors, professors and research scientists at institutions around the world to submit 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 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 UC Berkeley academic department. A list of current and former Miller Research Fellows can be found at: http://miller.berkeley.edu/fellowship/members/all-mf-by-name

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. A short period as a post-doctoral fellow elsewhere does not exclude eligibility. However, applicants who have already completed three years of post-doctoral experience are not eligible for nomination. **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 show eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. Non-US citizens will be required to prove English language proficiency prior to award. The Miller Institute does not support H1B visa status. The Fellowship term must commence between July 1 and September 1, 2019. Eligible nominees will be invited by email by the Institute to apply for the Fellowship after the nomination has been reviewed. 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 that will be valid through March 2019, 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 (saved in PDF format). 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 2% increases 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, 2019 and ending July 31, 2022. Approximately 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.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

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miller.berkeley.edu

Miller Research Fellowship Awardees 2018-2021

The Miller Institute is pleased to introduce the 2018-2021 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2018 academic year. A full list of all past and present Miller Fellows is available on our website.

Michael Abrams

Ph.D. - CalTech
Berkeley Dept. - MCB
Faculty Host: Nicole King

While doing my PhD in biology at Caltech, my advisor, Lea Goentoro, and I, used the phylogenetic position, self-repair capacity, and behavior of the moon jellyfish, Aurelia aurita, to better understand animal self-repair strategies. Simultaneously, in a collaboration between three labs at Caltech, we determined that a different species, the upside-down jellyfish, Cassiopea xamachana, displays a sleep-like state. These findings make Cassiopea an attractive system for better understanding how evolutionarily the sleep-like state is controlled, the role of sleep in an animal without a brain, and the extent to which sleep affects self-repair. The overall aim of my research is to tackle these questions in this early branching metazoan lineage, so that we may continue to demystify the ancient origins of sleep.

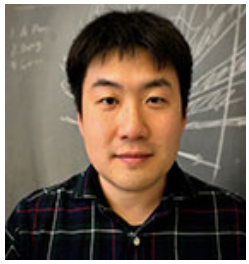
Lou Barreau

Ph.D. - CEA-NCRS Paris
Berkeley Dept. - Chemistry
Faculty Hosts: Steve Leone / Dan Neumark

Much of chemistry is governed by the electron motion among molecular orbitals that define the making and breaking of chemical bonds, occuring at the attosecond timescale (10^-18 s). I am interested in understanding, and eventually controlling, the ultrafast fundamental processes at play when an organic molecule absorbs light. To this end, my research uses ultrashort pulses in the soft X-ray domain, produced in the laboratory, to probe coupled electronic and nuclear dynamics in gas-phase species.

Private donations are becoming an increasingly significant resource for the Miller Institute. Your personal investment in support of the future of the Miller Institute will be greatly appreciated. Visit our: **"Make a Gift"** page at: ***miller.berkeley.edu/gift***

Soonwon Choi



Ph.D. - Harvard
Berkeley Dept. - Physics
Faculty Host: Dung-Hai Lee

My research interests lie at the interface of quantum many-body dynamics and information science. Combining tools from theory, numerical methods and experiments, I am interested in out-of-equilibrium quantum dynamics and their potential applications.

Alison Feder

Ph.D. - Stanford
Berkeley Dept. - Integrative Biology
Faculty Host: Oskar Hallastchek

Whereas most empirical and theoretical work has considered populations evolving to a single challenge, in nature, these challenges are often multiple and sometimes orthogonal. To understand evolution under complex and realistic circumstances, I combine genomic data and evolutionary theory to create biologically-grounded models of evolution to explain real world observations. I am particularly interested in how evolution in structured environments may allow populations to achieve evolutionary outcomes impossible in well-mixed populations.

Xiaojin (Ruby) Fu

Ph.D. - MIT
Berkeley Dept. - EPS
Faculty Host: Michael Manga

I am a geoscientist who studies multiphase and multicomponent flow in porous media through phase-field modeling and high-resolution simulations. My work seeks to unravel the complex coupling between multicomponent thermodynamics (phase transitions) and multiphase hydrodynamics (flow instabilities) in geologic multiphase mixtures, and provides mechanistic understanding of their nonequilibrium behaviors. I hope to apply these understandings to advance our predictive capability of multiphase systems in Earth science applications, including gas hydrates, volcanic systems and subsurface carbon storage.

Samuel Hopkins

Ph.D. - Cornell
Berkeley Dept. - EECS
Faculty Host: Luca Trevisan / Prasad Raghavendra

Extracting useful information from large, high-dimensional, and noisy data sets is a major computational challenge. I study algorithms for such statistical inference problems from a mathematical perspective, to understand which can be accomplished with limited computational resources, which cannot, and what principles underlie this distinction.

Ambika Kamath

Ph.D. - Harvard
Berkeley Dept. - ESPM
Faculty Host: Damian Elias

I am a behavioral ecologist broadly interested in the consequences of individual variation in behavior for the ecological and evolutionary trajectories of populations and species. I study how animals use and move through the space they occupy, because an animal's movement how easily and how often it encounters other individuals or particular habitats, and thus dictates the selective pressures it faces. My postdoctoral research explores questions of coevolution between animal architecture and collective behaviors in Stegodyphus social spiders, to understand if the spatial environments these animals build for themselves facilitate the adaptive social interactions that help their colonies succeed.

Georgios Moschidis

Ph.D. - Princeton
Berkeley Dept. - Mathematics
Faculty Host: Maciej Zworski

According to the general theory of relativity, gravity is perceived as the effect of the warping of the geometry of spacetime on the motion of observers; the spacetime geometry, in turn, depends on the distribution of matter through the celebrated Einstein's field equations. Recently, my research has focused on the study of instability phenomena associated to the Einstein equations in the presence of a negative cosmological constant. I am also interested in the stability properties of the scalar wave equation (a linear toy model for the Einstein equations) on a broad class of isolated, self-gravitating systems

Nicholas Rodd

Ph.D. - MIT
Berkeley Dept. - Physics
Faculty Host: Surjeet Rajendran

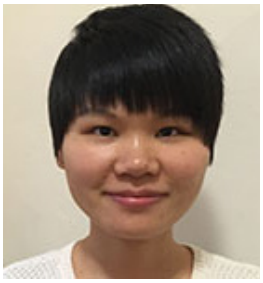
Dark matter is a substance that permeates the universe and is more than five times as abundant as regular matter, yet we have no idea what it is. My research looks to uncover the nature of dark matter by searching for the unique fingerprints it might leave in the datasets collected by telescopes looking out at the universe. Sitting right at the intersection of particle physics and astrophysics, my work involves making precise predictions for what these instruments should see, as well as talking to experimentalists to help them optimize their search strategies.

Rebecca Tarvin

Ph.D. - University of Texas Austin
Berkeley Dept. - Integrative Biology
Faculty Host: Rasmus Nielsen

Every major branch of life has evolved chemical defenses of some kind, despite the potential cost of utilizing toxic compounds. Naturally occurring toxins have been called keystone molecules because of their ability to influence organisms and the ecosystems in which they live. My aim is to experimentally evolve toxin-sequestering fruit flies to reveal the genetic processes and physiological trade-offs that drive the origins of this intriguing ecological adaptation.

Yong Zheng



Ph.D. - Columbia
Berkeley Dept. - Astronomy
Faculty Host: Daniel Weisz

Spiral galaxies form, grow, and evolve. Their disks are actively forming stars, while their halos are large reservoirs full of ionized plasma surrounding the star-forming disks. In theory, the disks thrive on inflows from the halos while the halos are enriched and heated by outflows from the disks. My research focuses on understanding how inflows feed the galaxies' disks and outflows stir their halos via observations with Hubble Space Telescope and ground-based instruments.

> CONTINUED FROM PAGE 1 [Miller Fellow Focus]

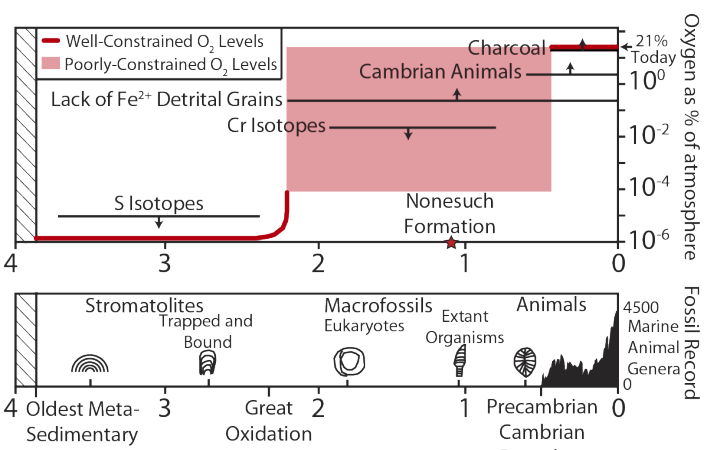


Figure 1: Prevailing view of atmospheric oxygen levels over Earth History and the fossil record of early life. In the top plot, constraints from different proxies for oxygen are shown; not all proxies agree with each other causing large uncertainty on the levels of oxygen from 2.3 to 0.4 billion years ago. Modified from Fischer (2016) PNAS, 113(7), 1686-1688.

With wide ranges of possible atmospheric oxygen levels, there are also large uncertainties about aqueous redox conditions; lower oxygen levels than today suggest waters could become anoxic/ferruginous (< 5 micromolar O_2) or euxinic (anoxic and sulfidic) at depth. A compilation published this year of the oxidation state of iron in volcanic rocks that erupted on the seafloor and interacted with surrounding seawater has suggested the deep open ocean was anoxic until 0.5 billion years ago. Geochemical analyses of iron in sedimentary rocks deposited in basins closer to shore suggest a predominance of ferruginous waters during this time period. Could these environmental conditions be connected to the prolonged delay after eukaryotic life arose ca. 2 billion years ago before more complex animals originated 0.7 billion years ago?

My research studies iron mineralogy and chemistry in sedimentary rocks by combining magnetic and microscale textural techniques to provide a window into ancient redox conditions. Now a second year Miller Fellow, I have been working in the Department of Earth and Planetary Sciences with my faculty host Nicholas Swanson-Hysell to study the ancient lake sediments from the 1.1 billion-year-old Nonesuch Formation. We are interested in understanding the environmental conditions of Paleolake Nonesuch since it was home to diverse life—the rocks contain microfossils of over 50 different species including several eukaryotes. Paleolake Nonesuch was large (at least 250 km long) and located near the equator; through subsequent plate tectonic motion, the sedimentary record of the lake is now located in Wisconsin and Michigan, USA. The Nonesuch Formation is one of the only lake records for its time and is very well-preserved making it a prime target for understanding conditions within ancient terrestrial environments.

Rock magnetic techniques can sensitively identify and quantify nanophase magnetic minerals down to parts per billion levels. Ferromagnetic minerals have distinct properties such as their coercivities, which is the resistance of a mineral to changing its magnetization when a field is applied, and their characteristic temperature-dependent magnetic transitions. I am conducting rock magnetic experiments on samples across the Nonesuch Formation and have found a clear change in iron mineralogy and abundances (**Figure 2**). Samples from deep water contain low abundances of the mineral magnetite ($Fe^{2+}Fe^{3+}_2O_4$), whereas samples from shallow waters contain abundant hematite ($Fe^{3+}_2O_3$). Sediments from intermediate water depths contain both abundant magnetite and hematite. Light microscopy and electron microscopy, paired with energy dispersive spectroscopy, corroborate this changing mineralogy and allow us to identify additional minerals relevant to the redox conditions of the ancient environment. Observations of texture, shape, and cross-cutting relationships reveal the relative timing of iron-mineral formation—for example, whether minerals were delivered to the lake as detrital grains, preserving information about the redox environment of rivers and the water column, or were authigenic, forming within the sediments after deposition.

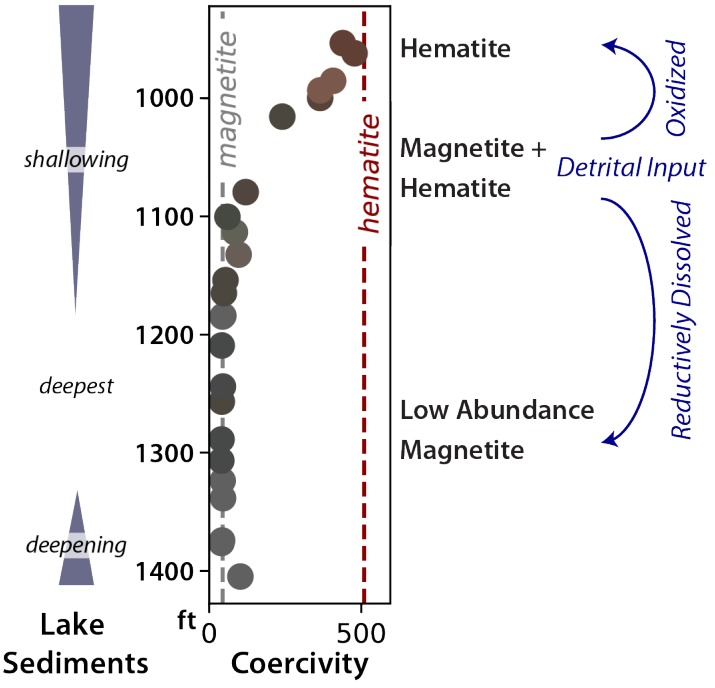


Figure 2: Coercivity data from sediments deposited across the entire temporal duration of Paleolake Nonesuch. The footage is drill core depth, and age increases with depth. After an initial deepening, the lake level shallowed over time (as noted by the blue bars), and sediments record deep to shallow waters upwards. Coercivity is a characteristic property of ferromagnetic minerals; average coercivities for magnetite ($Fe^{2+}Fe^{3+}_2O_4$) and hematite ($Fe^{3+}_2O_3$) are plotted as lines. Each data point is colored based on the true color of the sedimentary rock sample. Coercivity and other magnetic measurements reveal a progressive change in iron mineralogy from magnetite to magnetite + hematite to hematite as Paleolake Nonesuch shallows over time. The application of microscale textural methods allows for the interpretation of this change in blue.

Based on these observations (**Figure 2**), we interpret that rivers delivered a mixed assemblage of magnetite and hematite grains to the lake. The preservation of both reduced Fe^{2+} and oxidized Fe^{3+} phases suggests oxygen levels between fully oxic to suboxic. In deeper waters, both of these iron oxides were reductively dissolved either through the anaerobic microbial metabolism of dissimilatory iron reduction or abiotically through interaction with sulfide formed through anaerobic microbial sulfate reduction. Therefore, the low abundance of magnetite we observe and the formation of authigenic iron sulfide minerals are due to local anoxia in the deepest waters of the lake or within the waters filling gaps between sediment grains. In contrast, the shallowest waters record complete oxidation of the detrital magnetite into hematite, which would have occurred in oxic conditions.

Combining our data, we interpret much of Paleolake Nonesuch's water column to have been oxygenated with decreasing dissolved oxygen concentrations at depth leading to suboxic and anoxic conditions as in modern lakes. This picture that emerges through these multi-disciplinary methods is much clearer than that from bulk chemical characterization alone. While geologically short-lived, the ca. 1.1 billion-year-old Paleolake Nonesuch would have been hospitable for early eukaryotes for much of its temporal duration. Further work during my time as a Miller Fellow will use paleomagnetism, measurements of the ancient magnetic field trapped in these rocks, to date the different iron minerals, providing absolute age constraints beyond the relative timing from texture. My research as a Miller Fellow has shown the utility of applying magnetic techniques to new scientific questions and added valuable new data to our growing understanding about environmental conditions during early eukaryotic development and diversification.

Sarah Slotznick grew up in the forested hills outside of Hershey, Pennsylvania. She got her S.B. at the Massachusetts Institute of Technology before spending time as a park ranger and scientist in three US National Parks where she discovered her love of Earth History and the stories captured in rocks. Sarah went to graduate school at the California Institute of Technology where she completed her PhD in Geobiology with Woodward Fischer and Joseph Kirschvink. In her free time, Sarah enjoys traveling the world, attending live musical theater, and reading fiction especially fantasy, sci-fi, and mysteries.

Contact: sslotz@berkeley.edu

Call for Nominations

Miller Research Fellowship 2019-2022

Online Nomination Deadline: September 10, 2018

In the News

(see more past & current Miller Institute News: miller.berkeley.edu/news)

Barbara Meyer (Miller Senior Fellow 2013-2018) has been recognized by the Genetics Society with the **2018 Thomas Hunt Morgan Medal** for her groundbreaking work on chromosome behaviors that govern gene expression, development, and heredity.

Three Former Miller Fellows are among the **2018 Sloan Fellowship Awardees**:

- **Qian Chen** (Miller Fellow 2012 - 2015) is credited for her research of the new paradigm of building, mesoscopic imaging, and understanding active soft matter, the artificial materials analogue of smart living systems.
- **Rebekah (Bekki) Dawson** (Miller Fellow 2013 - 2015) is honored for insights into extra-solar planets, debris disks, dynamics of planetary and satellite systems, the Kuiper Belt, planet formation, signal processing.
- **Norman Yao** (Miller Fellow 2014 - 2017) is recognized for exploring uncharted territories at the interface between AMO physics, condensed matter, and quantum information science.

Michael Jordan (Miller Professor 2008, 2017-2018) is a co-lead of the Expeditions project. The **NSF Expeditions in Computing Award** was one of three announced by the National Science Foundation for research teams pursuing large-scale, far-reaching and potentially transformative research in computer and information science and engineering. **Professor Jordan** has also been named a **Plenary Lecturer at the 2018 International Congress of Mathematicians (ICM)**, an honor that has been bestowed on only a small handful of computer scientists over the 121 year history of the ICM.

2018 UC Berkeley Distinguished Faculty Mentor Awards:

- **Marla Feller** (Miller Institute Executive Director, Miller Fellow 1994 - 1996) - is honored for her commitment to equitable access and opportunity in the sciences, as well as her support for a broad range of researchers – from graduate students, to postdocs, to other faculty members.
- **Britt Glaunsinger** (Miller Professor 2015) - is recognized for her commitment to scientific communication and individual development; her innovations in providing holistic and structured mentorship have ensured success for her students.

Susan Marqusee (Miller Professor 2016-2017) is the 2018 recipient of The Protein Society's **Dorothy Crowfoot Hodgkin Award**, which recognizes researchers in protein science whose contributions have significant impacts in the broader field of biology. She is a world expert in the field of protein folding, and her influential research "has produced the most detailed view of the energy landscape of a protein."

Omar Yaghi (Visiting Miller Professor 2009) was awarded the **2018 Wolf Prize** for "pioneering reticular chemistry via metal-organic frameworks (MOFs) and covalent organic frameworks (COFs)."

Claude-André Faucher-Giguère (Miller Fellow 2010 - 2013) has been named as one of the **2018 Cottrell Scholars** for his innovative research proposal and education program, "The Physics, Observational Signatures, and Consequences of Galactic Winds Driven by Active Galactic Nuclei."

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Miller Institute News - Spring 2018
Please send address corrections to:
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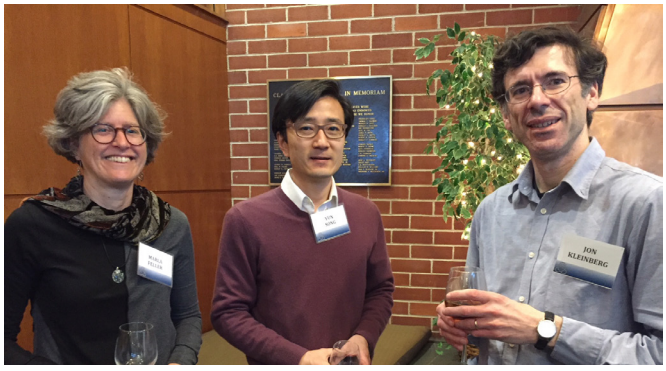
Spring Dinner 2018

(see more past & current Miller Events: http://miller.berkeley.edu/events/miller-events)

Miller Fellow Kelly Nguyen, former Executive Director Professor Jasper Rine, Miller Fellows Cara Brook, Amy Goldberg and Grant Remmen



Executive Director Marla Feller, Executive Committee Member Yun Song and guest speaker Professor Jon Kleinberg

Birth Announcements

Angelos Michaelides (Somorjai Visiting Miller Professor 2013) and his wife, Michelle welcomed their second baby, Penelope Anna Michaelides, born January 3, 2018.

Online Newsletter

The Miller Institute invites you to enjoy our previous e-newsletters by visiting: http://miller.berkeley.edu/news/newsletters

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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