

The Orbital Evolution of Planetary Systems

Miller Fellow Focus: **Rebekah Dawson**

We used to think that after planets form, they follow their orbits like clockwork. But over the past two decades, many planets outside our Solar System (extra-solar planets) and small bodies inside our Solar System have been discovered on surprising orbits, leading us to question whether the histories of planetary systems were really so uneventful. Planets are thought to form — out of a disk of gas and dust — on circular, coplanar orbits yet have been discovered on orbits that are highly elliptical, tilted out of the plane of their star's rotation, and at separations from their stars too close for formation. Copernicus, Kepler, Titius, and other early practitioners of celestial mechanics interpreted the harmonious regularity of planetary orbits in our Solar System as the signature of a divine architect. Yet even here in our Solar System, the elliptical, inclined, and resonant orbits of small bodies beyond Neptune, such as Pluto, are archaeological evidence of a more violent history, during which the Solar System's planets underwent orbital evolution and stirred up the small bodies in the process. Modern practitioners of celestial mechanics are working to identify which physical processes (Figure 1) drive the orbital evolution of planetary systems and the conditions under which the processes operate. The processes driving orbital evolution form



an essential context for interpreting the present-day properties of extra-solar planets, which are being discovered in abundance today and whose compositional properties and suitability for life will be probed in greater detail using the next generation of telescopes.

Second-year Miller Fellow Rebekah (Bekki) Dawson is studying the processes of orbital evolution through a combination of computer simulations, simple analytical models, and new approaches for analyzing and interpreting the rich and growing exoplanet dataset. Her dissertation work at Harvard University, supervised by Ruth Murray-Clay and in collaboration with John Johnson, focused on planetary "migration," a type of orbital evolution that alters a planet's separation from its star. Planetary migration has been invoked to explain

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Call for Nominations:

Miller Research Fellowship Nominations

Deadline: **Wednesday, September 10, 2014**

Miller Research Professorship Applications

Deadline: **Thursday, September 18, 2014**

Visiting Miller Professorship Departmental Nominations

Deadline: **Friday, September 19, 2014**

See page 5 for more details.

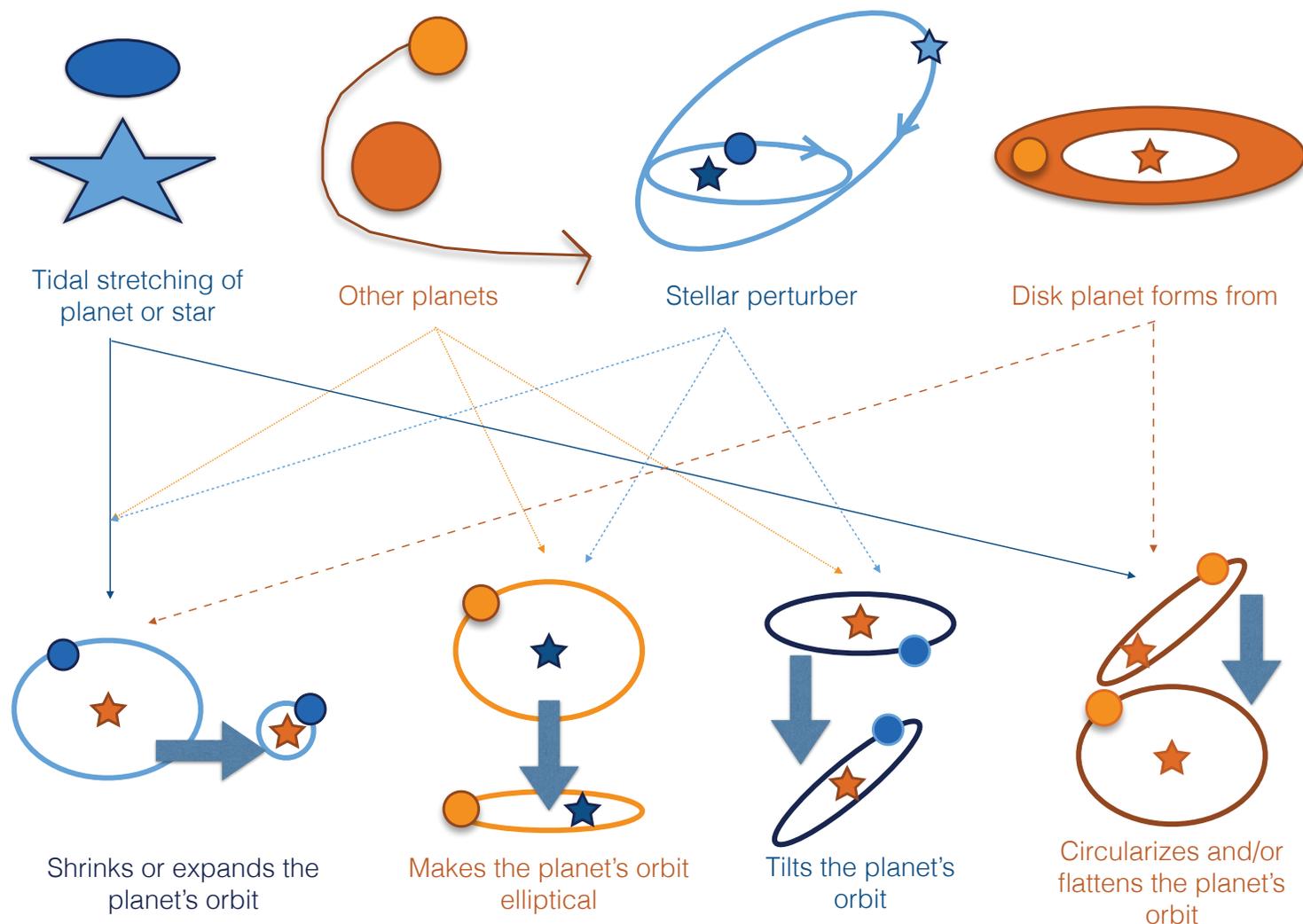
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MillerInstitute.berkeley.edu

"The Miller Institute is an elite organization where young professionals with the highest achievement levels in sciences and engineering are rewarded with fellowships that further embellish their reputation."

Gabor Somorjai
University Professor of Chemistry, University of California
National Academy of Sciences, National Medal of Science,
The Priestley Medal, The Wolf Prize, Miller Professor,
Miller Senior Fellow



Figure 1. Planets on the move. A variety of physical processes have been proposed for driving the orbital evolution of planets. The large number of arrows, processes, and outcomes in this figure represent our current state of ignorance. Which processes are important and under what conditions they are operate are open questions in modern celestial mechanics.



the surprisingly close-in orbits of “Hot Jupiters,” a mysterious population of extra-solar planets with sizes and masses similar to Jupiter but orbiting much closer to their stars than Mercury orbits to the Sun. Here in our Solar System, the orbits of small bodies beyond Neptune are thought to have been sculpted by Neptune’s migration. Using evidence from the eccentricities (elliptical orbital shapes) of giant extra-solar planets and small Solar System bodies, Bekki argued that gentle migration caused by the disk from which planets form and violent migration triggered by gravitational interactions among planets both play an important role in shaping the architectures of planetary systems.

Although planets are thought to form in a flat disk, some of the physical processes proposed for driving orbital evolu-

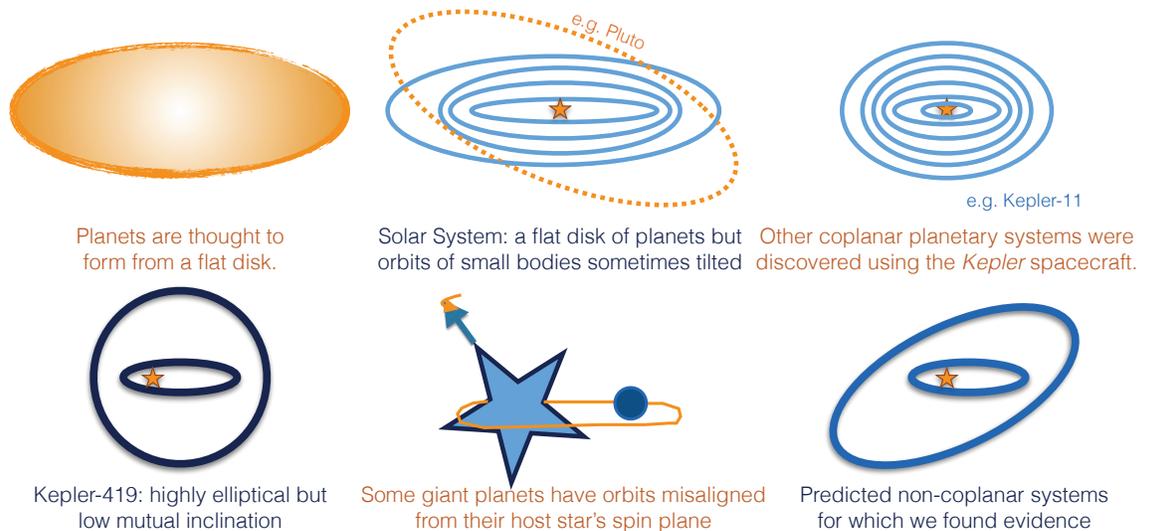
tion (Figure 1) can tilt a planet’s orbit out of the plane it formed in. Measuring the mutual inclinations among planets in a system is therefore a key test for distinguishing among the proposed processes. However, so far the evidence for mutual inclinations has been ambiguous. Our Solar System’s full-fledged planets are coplanar, but many of its small bodies have sizable inclinations, such as Pluto, which is tilted out our Solar System’s plane by about 30 degrees, and Narvi, a moon of Saturn, tilted by about 150 degrees. Intriguingly, many Hot Jupiters (discussed above) have orbits that are strongly tilted out of their host stars’ rotation planes, a configuration known as “spin orbit misalignment.” On the other hand, a population of coplanar systems of small, close-in planets have been discovered using data from the *Kepler* spacecraft. Several examples of flat and mutually inclined systems are illustrated in Figure 2.



At Berkeley, Bekki has been expanding her investigation of orbital evolution to three dimensions. Using data from the Kepler spacecraft combined with observations conducted from ground-based telescopes, Bekki and her collaborators, including UC Berkeley astronomer Kelsey Clubb, found that the exoplanets in the Kepler-419 system are coplanar (Figure 2). This system was an excellent case study for two reasons. First, the inner planet has a close-in, elliptical orbit, exactly the type of orbit that some theories predict should also be tilted. Second, the outer planet was not detected directly by the *Kepler* spacecraft, only indirectly through its gravitational perturbations on the inner planet's orbit; therefore the system was not subject to the biases that usually make *Kepler* sensitive only to flat planetary systems. In another recently published study, Bekki showed that several trends with stellar and planetary properties in the "spin orbit misalignments" mentioned above can be accounted for by tides raised on the host star by its close-in, giant planet. Most recently, Bekki and her Miller host, former Miller Professor Eugene Chiang, found evidence for a special class of planetary systems with large mutual inclinations. These systems feature two massive planets on elliptical orbits, the inner of which has stalled in its migration.

include UC Berkeley former Miller Professor James Graham and Professor Paul Kalas, will discover young planetary systems and disks of debris analogous to the small bodies beyond Neptune. In collaboration with the UC Berkeley team, Bekki is working on ways to interpret the structures of debris disks as archaeological evidence of the early orbital evolution of planetary systems. Bekki's work has greatly benefitted from helpful discussions with UC Berkeley former Miller Professor Geoff Marcy's team of exoplanet observers, participants in the Center for Integrated Planetary Science seminar organized by UC Berkeley professor Burkhard Militzer, UC Berkeley former Miller Professor Eliot Quatert's group, former Miller Fellow Eric Ford, and former Visiting Miller Professor Scott Tremaine.

Figure 2. A 3D view of planetary systems.



The three dimensional architectures of planetary systems constrain and distinguish theories of orbital evolution and therefore inform us indirectly about the fourth dimension, time. More directly, Bekki hopes to catch planetary systems in the act of orbital evolution with several projects currently underway. She is searching for changes in the inclinations of giant planets over the course of the four-year Kepler Mission and conducting a study to identify the best ways to account for the correlated noise — caused by stellar and instrumental variability — that makes this measurement so challenging. Bekki is developing a statistical framework to assess the robustness of apparent trends between planetary orbital properties and stellar ages. Finally, the Gemini Planet Imager Survey, whose Lead co-Investigators

On a family vacation fifteen years ago, Bekki ran out of novels and her father lent her the popular science book he was reading, *A Brief History of Time*. The descriptions of time travel and black holes led Bekki to one day sign up for an introductory Astronomy class at Wellesley College taught by Richard French, but she ended up being most fascinated by the section about planets. She credits Wellesley's strong commitment to undergraduate research, especially a research experience the summer after her first year, for kindling her spark of interest in astronomy. She continues to spend most of her free time reading novels and also enjoys cooking and rambles on Berkeley's 140 walking paths.

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From the Executive Director



Summer is always a season of transition at the Miller Institute. New members arrive, and Miller Fellows move on. Once again, the departing fellows leave with promising futures, as will be clear from “next steps” listed on the back page.

We are pleased to share the news that Geoff Marcy from astronomy will be joining the Institute as the next Miller Senior Fellow. Professor Marcy is best known

for discovering and characterizing extrasolar planets. He is familiar to many former members of the Institute as he was both a dinner and symposium speaker, a former Miller Professor, and has hosted Miller Fellows. During his 15 years on campus he has demonstrated an exceptional ability and willingness to mentor and inspire, from the students he teaches to his professional colleagues. His formal appointment will begin in September 2015 following a sabbatical that spring, but we look forward to Professor Marcy participating in Institute activities beginning this fall.

There are a few other changes. Claude Canizares from MIT finished his term on the Advisory Board. He will be replaced by Roger Blandford from Stanford. Professor Blandford knows us well because he just finished an appointment as a Visiting Miller Professor, and participated

in dinners and the annual symposium. Gabor Somorjai completed his term as Miller Senior Fellow and, like Randy Schekman, has agreed to continue participating in Miller Institute activities.

The Miller Institute will be celebrating its 60th anniversary in 2015-2016 with an array of lectures and other events. Stay tuned. Jasper Rine will be taking a leave from the Executive Committee for one year in order to plan and organize the year-long celebration. Stepping in for Jasper will be Kathleen Collins, former Miller Professor from Molecular and Cell Biology.

Some things at the Miller Institute do not change. Our mission is support Basic Research in Science and the creative individuals who do this science. We continue to value scientific interactions and an exchange of ideas across disciplines – the reason we continue the weekly lunches, happy hours, dinners and annual symposium. Some personal highlights this year include Bob Full’s inspiring dinner talk about biolocomotion; Feryal Ozel’s lunchtime talk about the cloud of gas being sucked into our black hole; and Blake Sherwin’s impromptu Powerpoint-free explanation of primordial gravitational waves, complete with captivating hand gestures. Our Visiting Miller Professors also contributed to many lively happy hour discussions. We welcome, nevertheless, all your ideas about new directions, opportunities or events that would enrich the experience of current and past members of the Institute.

Sincerely, Michael Manga
Executive Director of the Miller Institute &
Professor of Earth and Planetary Science

Geoff Marcy Named 2015 Miller Senior Fellow

The Miller Institute is pleased to name Geoff Marcy the 2015 Miller Senior Fellow for a term beginning September 1, 2015.

Professor Marcy is a Professor of Astronomy at UC Berkeley. He is an elected member of the National Academy of Sciences and has been the recipient of numerous awards, including the NASA Medal for Exceptional Scientific Achievement. He was named Discovery Magazine’s Space Scientist of the Year in 2003. He was also co-recipient of the prestigious Shaw Prize.

Dr. Marcy finds and characterizes exoplanets. He and collaborators have discovered over 250 extrasolar planets, allowing ongoing study of their masses, radii, and orbits, including eccentricities and misalignments. His research team discovered the first multiple planet system (Upsilon Andromedae), the first Saturn-sized planet, and the first Neptune-size planet. He was a co-investigator with the NASA Kepler mission that recently announced over 4000 exoplanets, most being smaller than twice the size of Earth. He and collaborators have demonstrated that many of them are rocky, like Earth, and that

20% of stars have lukewarm, Earth-size planets. His current research focuses on finding other Earth-size planets and solar systems similar to our own. Ongoing work is designed to study the sizes, occurrence frequency, chemical composition, and the orbits of Earth-size planets. He also searches for signs of extraterrestrial technological civilizations.



Geoff Marcy

As the sixth Miller Senior Fellow named, Marcy will join Saul Perlmutter, Professor of Physics, Raymond Jeanloz, Professor of Earth & Planetary Science and Barbara Meyer, Professor of Molecular and Cell Biology, as part of our community of world-renown scientists. Taking its place alongside the Institute’s other programs: the Miller Fellowships, the Miller Research Professorships and the Miller Visiting Professorships, the Miller Senior Fellow Program was established in 2008. Its purpose is to support excellence in basic science at UC Berkeley by providing distinguished faculty on campus with significant discretionary research funds and by involving them in the activities and intellectual fellowship of the Miller Institute. The Miller Senior Fellow Program enhances the Institute’s mission by fostering interactions between distinguished senior scientists in different disciplines and our postdoctoral Fellows.



Call For Nominations: Miller Research Competitions

Miller Research Fellowship 2015-2018

Online Nomination Deadline: Wednesday, Sept. 10, 2014

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 have a keen curiosity about all science and 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. A list of current and former Miller Research Fellows is available on our website.

Qualifications:

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, candidates who have already completed substantial postdoctoral training or other work 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, which can run into February. Nominees who are non-US citizens must show eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. The Miller Institute does not support H1B visa status. Eligible nominees will be invited by the Institute to apply for the fellowship. Direct applications and self-nominations are not accepted.

Abbreviated Terms of Appointment:

- + Miller Fellowships are granted for a period of three years. Starting dates are negotiable but must commence between July 1 & October 1.
- + The Institute provides a stipend of \$63,000 with annual increases.
- + Miller Fellows are entitled to all normal holidays observed by the University; are granted an annual bank of 24 days of personal time off and twelve days of sick leave annually.
- + Miller Fellows receive a research fund of \$10,000 per annum.
- + There is provision for travel to (but not away from) Berkeley for Miller Fellows and their immediate families and an additional allowance of \$3,000 for the transport of personal belongings.
- + Benefits including medical, dental, vision, short term disability and life insurance are provided, with Miller Fellows making a small contribution towards the premium. Long term disability is voluntary.
- + All University of California postdocs are exclusively represented by the UAW and are subject to the terms of the contract including payment of membership dues or agency fees.
- + Approximately eight to ten Fellowships are awarded each year.
- + Candidates will be notified of the results of the competition between mid-December and mid-February, and a general announcement of the awards will be made in the spring.

Nomination & Application details: MillerInstitute.berkeley.edu

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

Miller Research Professorship 2015-2016

Online Application Deadline: Thursday, Sept. 18, 2014

The Advisory Board of the Miller Institute for Basic Research in Science welcomes faculty from the University of California Berkeley to submit an application for a Miller Professorship term in the 2015-2016 academic year. The purpose of the Miller Professorship is to release members of the Berkeley faculty from teaching and administrative duties and allow them to pursue research on the Berkeley campus. Appointees are encouraged to follow promising leads that may develop in the course of their research effort whether or not they fall within the original research outline. Applications are judged competitively.

Applicants who are not members of the Berkeley faculty should seek affiliation with and a nomination through an academic department at Berkeley for the Visiting Miller Professorship Program.

Miller Professors will retain their academic appointment in their home department, but will be placed on a modified status relieving recipients of teaching obligations during the appointment term. Awardees are expected to devote full time and effort to basic research.

Additional terms are posted on the Miller Professorship webpage. Candidates will be notified of the results in December.

Visiting Miller Research Professorship AY15-16

Online Nomination Deadline: Friday, Sept. 19, 2014

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. The purpose of these is to bring promising or eminent scientists to the Berkeley campus on a short-term basis for collaborative research interactions. The Somorjai Award generally supports an early-career visiting scientist within the broad field of chemical sciences for a one-month term. Both programs require that awardees are in residence at Berkeley during their appointment term, and it is the department host faculty member's responsibility to ensure their presence on campus. It is stipulated that the appointee do no formal teaching, however public talks and department colloquia are encouraged. All absences away from the Berkeley campus during the award term must be coordinated with the Miller Institute office in advance and payments will be adjusted accordingly.

Terms of appointment may range from a minimum of thirty days to a maximum of one semester (120 days). Full semester appointments are encouraged and nominations should include justification, within the research proposal for this long-term collaboration. Each appointment starting date will be negotiated separately, with the restriction that appointments must take place during either Fall 2015 or Spring 2016 of the regular academic year. 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. Visitors cannot be supported on H1B or B visas. Announcements of the awards will be made in December.



In the News

Michael Jordan (Miller Professor Fall 2008) is the 2015 recipient of the **David E. Rumelhart Prize**, a prestigious honor reserved for those who have made fundamental contributions to the theoretical foundations of human cognition.

Xiang Zhang (Miller Professor 2011-2012) and his team of researchers were highlighted in the UC Berkeley News Center for having found a way to dramatically increase the sensitivity of a light-based plasmon sensor to detect incredibly minute concentrations of explosives. They are developing plasmon laser sensors that could soon compete with bomb-sniffing dogs.

Matthew Good (Miller Fellow 2010-2013) has been awarded the **2014 Career Award** through the Burroughs Wellcome Fund in the area of interface science.

Jeffrey Townsend (Miller Fellow 2002-2005),
Yi Cui (Miller Fellow 2003-2005) &

Alison Galvani (Miller Fellow 2002-2005)

Three former Miller Fellows with New York Academy of Sciences President Ellis Rubenstein and a bust of Charles Darwin, at the 2014 Blavatnik Science Symposium in New York City, where Professor Cui was honored as a Finalist for the **Blavatnik Award for Young Scientists**. Professor Galvani is a former Faculty Winner of the Blavatnik Prize, which celebrates the most innovative and promising faculty-rank scientists and engineers.



Jason Stajich (Miller Fellow 2006-2009) received national recognition by winning the **2014 Alexopoulos Prize** from the Mycological Society of America, a scientific society dedicated to advancing the science of mycology - the study of fungi of all kinds including mushrooms, molds, truffles, yeasts, lichens, plant pathogens, and medically important fungi.

Donald DePaolo (Miller Professor 1997-1998) Former ESD Director Don DePaolo, now LBNL's Associate Laboratory Director for Energy Science, was selected as this year's **AGU Harry Hess Medal** recipient. This award is given annually to one honoree in recognition of "outstanding achievements in research on the constitution and evolution of the Earth and other planets."

Jeremy Thorner (Miller Professor 1984-1985, 1999-2000) has been chosen to receive the **Lifetime Achievement Award** at the Genetics Society of America sponsored Yeast Genetics and Molecular Biology

Meeting. Professor Thorner was selected in recognition of his many scientific contributions and outstanding community service.

Mark Hauber (Miller Fellow 2002-2005) who received a **HFSP Young Investigator Grant**, was highlighted in the Human Frontier of Science newsletter (p. 7) for his new book entitled, "The Book of Eggs".

Saul Perlmutter (Miller Senior Fellow 2010-2015) & **Barbara Meyer** (Miller Senior Fellow 2013-2018) were elected members of the **American Philosophical Society**. They were 2 of the 3 UC Berkeley professors that were elected at the scholarly society's 2014 spring meeting in Philadelphia, where APS was founded in 1743.

Robert Bergman (Miller Professor 1982-1983, Fall 1993, Spring 2003) was named the 2014 **Welch Award in Chemical Research** recipient for "pioneering work in alkane activation and mechanisms of organometallic reactions."

NAS announced new members:

Richard Borcherts (Miller Professor 2000-2001)
Julian Davies (Visiting Miller Professor Spring 1988)
Daniel Eisenstein (Visiting Miller Professor Fall 2005)
Craig Evans (Miller Professor Fall 2001, Fall 2002)
Richard Harland (Miller Professor Fall 2010)
Angel Rubio (Visiting Miller Professor Fall 2014)
Joseph Silk (Miller Professor 1980-1981)
Montgomery Slatkin (Miller Professor Spring 1989, Spring 2000)
Eske Willerslev (Visiting Miller Professor Spring 2015)
Bin Yu (Miller Professor Spring 2004)

AAAS announced new members:

Kenneth Farley (Visiting Miller Professor Spring 2003)
Edward Frenkel (Miller Professor Spring 2013)
Daniel Tataru (Miller Professor Spring 2011)
Alex Zettl (Miller Professor 1995, Spring 2007)

Guggenheim Fellows named:

Ashvin Vishwanath (Miller Professor Fall 2009),
Jonathan Feng (Miller Fellow 1995-1997),
Jiaxing Huang (Miller Fellow 2004-2007),
Ray Jayawardhana (Miller Fellow 2000-2002) &
Jun Korenaga (Miller Fellow 2001-2002) were named Guggenheim Fellows. They were appointed on the basis of prior achievement and exceptional promise.

Kam-Biu Luk (Miller Professor Fall 2001) was awarded the **APS Prize: 2014 W.K.H. Panofsky Prize in Experimental Particle Physics**.

Garnet Chan (Miller Fellow 2000-2002) won the **William O. Baker Award** for Initiatives in Research.

Robert Kirshner (Visiting Miller Professor Spring 1994) won the **James Craig Watson Medal**.

Daniela Kaufer (Miller Professor Fall 2012) was featured on the UC Berkeley News Center in this article: "Commonly available blood-pressure drug prevents epilepsy after brain injury".

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



18th Annual Interdisciplinary Symposium



Visiting Miller Professor W. Craig Carter & Miller Fellow Tim Frolov.



Executive Committee member, Richard Saykally spices up the night with some music.



Advisory Board member Vaughan Jones & former Miller Fellow Adam Day.



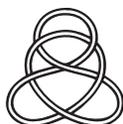
Miller Fellows Greg Bowman, Milo Lin, Eric Neuscamm, Gokhan Barin & Justin Kim.



Pre-symposium hikers enjoy Point Reyes.



Miller Senior Fellow Raymond Jeanloz emcees the weekend.



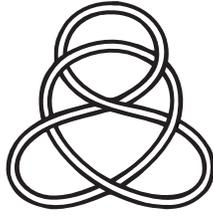
Speakers: David Lin, Boris Baer, Emily Brodsky & Ray Beausoleil



Executive Committee member, Jasper Rine & Miller Fellow Ashvini Shekhawat enjoy a break.



Speakers: Sonke Johnsen, Keith Devlin, Howard Stone & Alice Shapley



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Please send address corrections to:
miller_adm@berkeley.edu



Birth Announcements

Gregory Engel (Miller Fellow 2005-2008)
& Kelly Plummer announced the birth of their son,
Evan James Engel, born May 30, 2014.

Ray Jayawardhana (Miller Fellow 2000-2002)
& Kathryn announced the birth of their daughter, Nehara
Sonali Jayawardhana, born Feb 21, 2014.

Next Steps

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

- Greg Bowman** (Assistant Professor @ Washington University, St. Louis)
- Matt Good** (Assistant Professor @ University of Pennsylvania)
- Eric Neuscammann** (Assistant Professor @ UC Berkeley)
- Rachel Pepper** (Assistant Professor @ University of Puget Sound)
- Joshua Ruderman** (Assistant Professor @ New York University)

Make a Gift



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: MillerInstitute.berkeley.edu/gift

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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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