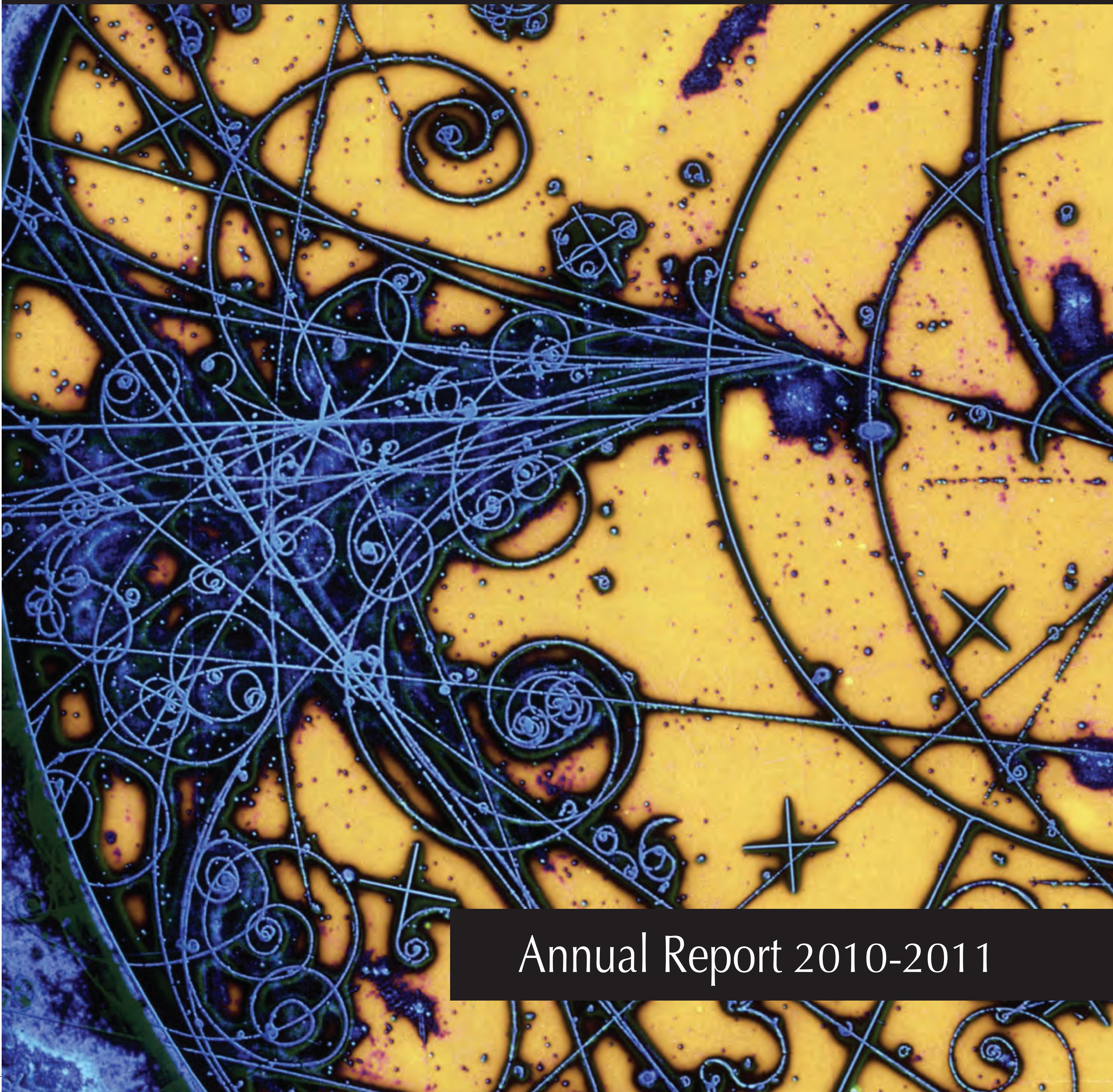
UCLA

# Department of Physics & Astronomy



## Annual Report 2010-2011

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2010-2011
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# Department of Physics & Astronomy

# 2010-2011 Annual Report

University of California, Los Angeles

# *Message from the Chair*

James (Jamie) Rosenzweig, Chair

As Chair of the UCLA Department of Physics and Astronomy, it is with pride that I present our 2010-11 Annual Report. This document is represents a snapshot of a fast-moving and exciting scenario, in which we attempt to distill the most compelling and newsworthy events affecting the department in the past 12 months. It is hoped that you, the reader, will find your curiosity piqued, and that you will be compelled to seek out more information on the myriad of cutting edge educational and research programs offered here. This information can be gleaned through the departmental web site, which I encourage you to consult for a more detailed and current picture.

In each year's annual report, in addition to summaries of research highlights from across the department, the spotlight is placed on one area in particular in our feature article. This year we present a portrait of our strong and multi-faceted elementary particle theory research group, in an article entitled "In Pursuit of Particles, Strings, and Black Holes". In it, you will find an intriguing description of this research group's work, which provides theoretical underpinning of experiments from frontier collider physics searches for the Higgs boson, to those investigating cosmological remnants of the Big Bang. Modern elementary particle theory is perhaps above all concerned with development of a unified theory of fundamental interactions; front line struggles in this thrust at UCLA include unique efforts in string theory and super gravity.

In addition to the focused spotlight of the feature article, this report gives vignettes of the impressive variety of recent research undertaken by departmental faculty. The themes embraced by UCLA physics and astronomy research indeed range, as appreciated even from the elementary particle theory alone, from the tiniest to the vastest length scales in the universe. UCLA physicists play lead roles in the search for the Higgs at the Large Hadron Collider, as well as other high profile experiments in elementary particle and nuclear physics. At the other end of the distance scale, UCLA astronomers investigate the intricacies of the galactic center and the cosmic microwave background using state-of-the-art telescopes such as the Keck, along with instruments developed in our world-leading Infrared Lab. UCLA is also home to a vigorous astro-particle program, which connects the ultra-small and the extra-galactic length scales through studies of fundamental cosmic particles and their interactions.

UCLA is also well represented in nanoscale physics, with fascinating work ongoing is novel systems ranging from the world's smallest light bulb to the most precise clock yet conceived based on extending the atomic clock concept to nuclear transitions. At atomic and molecular length scales, UCLA Dept. of Physics and Astronomy researchers often push frontier techniques in imaging, playing a leading role in opening new frontiers in coherent imaging using the X-ray free-electron laser — conceived and developed at UCLA — and ultra-fast electron diffraction.

These new techniques in X-ray and electron beams have been developed in the context of a unique program in advanced accelerators, based on lasers and plasmas here. This is only one aspect of plasma physics (the physics of ionized gases) research in the department, which also embraces frontier efforts extending from both magnetic and inertial confinement fusion, to laboratory plasma astrophysics.

The theme of advanced imaging extends to complex mesoscopic and macroscopic objects that are characteristic of biophysical systems. In this regard, UCLA hosts burgeoning programs in biophysics that are giving new insights into the physics of hearing hair cells, DNA function, and the mysteries of brain function. These hybrid areas require collaborations extending beyond departmental boundaries, between our faculty and chemists, biologists and engineers encouraged by the UCLA California Nanosystems Institute, as well as joint investigations between Department members and their counterparts in the world-class medical school at UCLA.

The faculty in our department has undergone a number of notable transitions in the past year: Dolores Bozovic, an experimental biophysicist concentrating on the physics of hearing received tenure this year; Alex Levine, a theoretical biophysicist UCLA Chemistry and Biochemistry has joined the department part-time; laser-plasma experimentalist Christoph Niemann's UCLA appointment was converted to full-time in physics. We greet Rahul Roy, a newly hired assistant professor in condensed matter theory. In a somber note, we also said a collective goodbye to our beloved colleague Charles "Chuck" Whitten, who sadly and suddenly passed at the end of 2011. He is gone, but very far from forgotten.

Our faculty has often been formally recognized through awards and prizes, and last year was no exception. Steven Furlanetto was awarded both the Helen B. Warner Prize from the American Astronomical Society and the Sloan Research Fellowship. Fellow astronomer Michael Fitzgerald was recognized with the AAAS Newcomb Cleveland Prize. Department members inducted into prestigious societies include Mayank Mehta, who was named a Foreign Member, The Royal Norwegian Society of Sciences and Letters, and Ned Wright, who received the impressive honor of joining the National Academy of Sciences. Finally we note with pride that the excellence in teaching in our department has reached a new height, in the example of Katsushi Arisaka, who received the highly competitive UCLA Distinguished Teaching Award.

Ian McLean, Vice Chair Astronomy

Prof. Arisaka's recognition points out that the dedicated efforts by the faculty, research staff and academic staff here are ultimately aimed at educating students, from undergraduates that are increasingly involved in research, to the high quality graduate students that are the true engine of research in the department. This report provides an update on the best of this new generation of scientists, who are the true measure of our success.

This brief welcome offers an introduction and orientation to the academic community that is our department. This community obviously extends to the alumni and valued benefactors, whose generosity is also spotlighted in this report. Whether you are interested in the UCLA Department of Physics and Astronomy as a potential colleague, student, or benefactor, or are simply curious about our educational and research activities, I invite you to explore this Annual Report.

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# In Pursuit of
## *Particles, Strings, and Black Holes*

Particle physicists have been planning for nearly 30 years for an accelerator capable of producing energies high enough to explore how elementary particles acquire their mass. Although the Standard Model provides an amazingly accurate description of the electroweak and strong forces, the generation of mass is tied to the Higgs, a particle that remains undiscovered.

The dream of such a powerful accelerator has now become a reality, ever since the Large Hadron Collider (LHC) started operations at Geneva's CERN laboratory. From the start, experimental particle physicists at UCLA have been involved in building one of LHC's detectors, and they are currently collecting and analyzing the vast amounts of data being produced.

Although the discovery of the Higgs is the primary focus of the LHC, it is neither the only one nor necessarily the most exciting one. After all, since the Standard Model does not include the force of gravity, it is incomplete in at least this respect; but perhaps it is incomplete in other respects as well. Pondering the missing pieces requires speculation, and this is the task and the realm of theoretical particle physicists. In fact, theories involving supersymmetry and extra space-time dimensions, whose roots may be found in the fertile soil of string theory, promise to predict not one but some 20 to100 new particles, which just might be discovered at the LHC.

Theorists at UCLA are exploring virtually every aspect of elementary particle physics. Novel methods for evaluating Feynman diagrams will make high-precision comparisons possible between theory and experiment. Quark confinement is being elucidated. The composition of dark matter and dark energy in the universe is being investigated. String theory is being applied to a wide variety of physical and mathematical problems, most recently to the relation between phase transitions of matter and the thermodynamics of black holes.

## Beyond Feynman Diagrams

As one of the 20th century's most brilliant minds, Richard Feynman gave the scientific world so much to chew on that modern researchers in theoretical particle physics like UCLA physicist Zvi Bern still consider Feynman's work to be a touchstone for their own investigations. Says Zvi, "Feynman diagrams give us a fantastically detailed description of how particles interact, along with the instructions to calculate their activity, but they run into problems due to an explosive growth in their complexity; the calculations quickly get out of control, using even the most powerful supercomputers."

The sheer complexity of more advanced Feynman diagrams led Zvi and his collaborators to resurrect the concept of unitarity, a methodology widely used in the 1960s to discuss strong nuclear interactions. Refitted to today's new physics, unitarity offers a shortcut for calculating Feynman diagrams with a reformulation in which all intermediate steps are in terms of physical quantities. This basic change has led to a flowering of many new ideas and results, from research groups around the world. More importantly, it offers new and remarkable insights into problems that have stumped generations of theoretical physicists. Zvi's research over the last several years has authenticated this new application of unitarity. Says Zvi, "The only way you can know you have devised a better method is you have do something important and interesting with it, something that could not have been done without it."

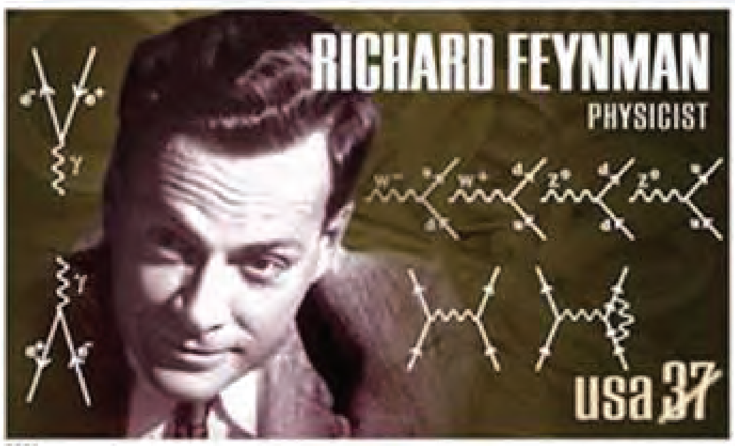
*New calculations show that quantum gravity is much better behaved than had been believed possible, renewing hope lost 30 years ago that simple variants of Einstein's gravity can be made consistent with quantum mechanics.*

Zvi and other theoretical physicists are using the unitarity method to analyze processes currently under experimental investigation at the Large Hadron Collider (LHC). Zvi is delighted to be working with UCLA experimental physicists Robert Cousins, Jay Hauser and David Saltzberg. "Finally, we [theoretical physicists] can get out of our self-prescribed mental cubicles and work directly with experimental physicists." Zvi and his collaborators have applied the unitarity method to obtain long-awaited theoretical predictions for recent experimental results at the LHC, in a series of articles published in Physical Review and Physical Review Letters.

Among other applications, Zvi has also applied the new unitarity tools to fundamental questions in quantum gravity. Can gravity and quantum mechanics be combined in a coherent picture free of the usual mathematical inconsistencies that have plagued attempts in the past to describe these forces in nature? In the past year, Zvi and his former

# *Feynman Diagrams*

Richard Feynman was a multifaceted scientist with contributions ranging from the atomic bomb to Mayan hieroglyphics to the Challenger disaster. His most significant legacy, however, lies in quantum physics. Among his many accomplishments, in the mid 20th century, he developed the ubiquitous tool of Feynman diagrams that continues to be a part of every graduate school curriculum in elementary particle physics.




Feynman's diagrams established a set of graphical rules that give modern physicists a visual picture of particle collisions together with detailed instructions for computing their probability of occurring. Originally applied to quantum electrodynamics (QED)—the quantum theory of light—in the early 1950s, Feynman diagrams were subsequently shown, in the 1970s, to work with gravity as well as the weak and strong nuclear forces.

Initially calculated by hand, Feynman diagrams were later solved with computers, though they rapidly lose their power as the processes become more complex, defying even today's most powerful supercomputers: this precludes some of the most enticing possibilities to probe the quantum nature of physics. Despite this obstacle, Feynman diagrams have remained a central tool of theoretical particle physics for over 50 years.

The recent development of the modern unitarity methodology, provides a shortcut to Feynman diagram calculations, and has breathed new life into such studies, especially as it relates to experiments conducted at the Large Hadron Collider and to quantum gravity.

doctoral students, John Joseph Carrasco and Henrik Johansson, used the unitarity method to identify a surprising new property of quantum gravity they called the "double copy." It shows that interactions of gravitons can be understood as two copies of the interactions of gluons—the carrier of the strong nuclear force—offering new insight into the quest for unifying gravity with the three other known forces of nature.

Zvi and his collaborators have used these ideas to theoretically probe quantum gravity at unprecedented levels, showing through the fourth quantum correction— called loops in the terminology of Feynman diagrams—that a variant of Einstein's theory of gravity known as N = 8 supergravity is much better behaved than had previously been thought possible. They are currently trying to get the fifth quantum loop under control. They then hope to prove that, contrary to expectations, the potential mathematical inconsistencies are actually not present, renewing an approach to quantum gravity that fell to the wayside 30 years ago.

Zvi has presented his findings at the recent Feynman Festival held at Caltech (see http://tedxcaltech.com/speakers/zvi-bern) and in a Scientific American article (to be published in 2012) with collaborators Lance Dixon (Stanford) and David Kosower (Saclay).

## Solving Astrophysical Puzzles

The convergence of theoretical elementary particle physics and astrophysics has led researchers like UCLA Prof. Alexander Kusenko into space. Alex is working toward an understanding of the early universe. Recently, he directed his investigations to identifying dark matter and to using gamma rays and cosmic rays to learn about universal photon backgrounds and magnetic fields.

Dark matter is observed by the effects of its gravity, but its identity remains a long-standing mystery. Not made of ordinary atoms, it must be composed of new, yet undiscovered particles. Identifying the nature of these particles will constitute a significant breakthrough.

Says Alex, "In order to detect the non-gravitational interactions of dark matter, we must first hypothesize the identity of dark matter, which is where theoretical physics comes in. Many candidates are being pursued." One such candidate is motivated by the discovery that neutrinos have mass. Neutrino masses imply that known "left-handed" neutrinos have "right-handed" counterparts, known as sterile neutrinos. In a certain mass range, sterile neutrinos can make up cosmo-

*Physicists have hypothesized for many years that a universal magnetic feld permeates deep space between galaxies, but there was no way to observe or measure it until now.*

logical dark matter. Observing their activity is exceedingly difficult because these particles interact very weakly, and laboratory experiments offer little hope of detecting them.

By venturing into space where large quantities of dark matter may contain sterile neutrinos, Alex has devised a different strategy from the standard approach on earth. In 2008, he teamed with Michael Loewenstein, a UCLA alumnus now working for NASA, to observe large clumps of dark matter in space with the use of x-ray telescopes that orbit the earth. Says Alex, "We think this represents the first dedicated search for dark matter using x-ray telescopes."

Alex and his NASA colleague gained approval to conduct observations with all three of the x-ray telescopes currently in orbit—Chandra, Suzaku and XMM-Newton. Alex and Michael are now analyzing and publishing their findings from the data collected thus far. They are making good progress, and the addition of a new telescope in a few years will give them even more opportunities.

Moving in a different direction, Alex and UCLA doctoral student Warren Essey (now a postdoc at UC Berkeley) have proposed a compelling explanation of why some very energetic gamma rays reach us from much farther away than expected.

Gamma rays with energies of trillions of electron volts should interact with starlight in intergalactic space and lose energy quickly. Yet, such gamma rays have been detected from extremely distant blazars. (Blazars are giant black holes that devour stars and accelerate particles to very high energies in powerful jets.) Alex explains, "This puzzle can be explained if the contribution of cosmic rays, which can be produced in the same sources, is taken into consideration. While gamma rays lose steam on their way to earth, cosmic ray protons travel unimpeded and produce additional gamma rays to replace those that are lost. The spectacular agreement of the predicted spectra with the data confirms this hypothesis and provides the first experimental evidence that cosmic rays are accelerated by supermassive black holes." This phenomenon has long been suspected, but never proven.

The signals from distant blazars provide an exciting opportunity to learn about intergalactic magnetic fields and the density of starlight. Alex, Warren and Shin'ichiro Ando from Caltech have obtained evidence of magnetic fields permeating deep space between galaxies that may date back to the time of the Big Bang. Using two independent techniques, they set lower and upper limits on intergalactic magnetic fields, which appear to have the strength of a femtogauss, or one-quadrillionth of the earth's magnetic field.

## Dark Matter

Although dark matter makes up most of the matter in the universe (estimated at 83 percent), its interactions outside of gravity are unknown. Astrophysicists do know, however, that dark matter is not composed of ordinary atoms.

Because it neither emits nor scatters light, dark matter cannot be directly detected via optical or radio astronomy. Astrophysicists infer its existence from gravitational effects on visible matter, making it a perfect topic for theoretical particle physicists. Making educated guesses about how dark matter particles might interact, they choose potential candidates that might make up these particles and study them using a variety of approaches.

Some dark-matter candidates are suggested by indirect clues that come from fundamental laws of physics. In the 1970s, UCLA Prof. Roberto Peccei and Stanford physicist Helen Quinn pointed out an appealing way to resolve a difficult theoretical puzzle: Why do strong interactions treat matter and antimatter in the same way, and why do they not distinguish between left and right or time going forward and backward. The solution led to the famous Peccei-Quinn symmetry. If this elegant solution is realized in nature, a particle accompanying Peccei-Quinn symmetry, called axion, can be dark matter. Other candidates are suggested by beautiful theoretical ideas about what lies beyond known physics; supersymmetry is an example.

The discovery of neutrino masses points to another dark matter candidate—the sterile neutrino. The search for sterile neutrinos is leading researchers into outer space, where an abundance of dark matter may provide better opportunities to observe this skittish particle. Research currently conducted in the physics department at UCLA is aimed at this possibility.

# The World According to String Theory

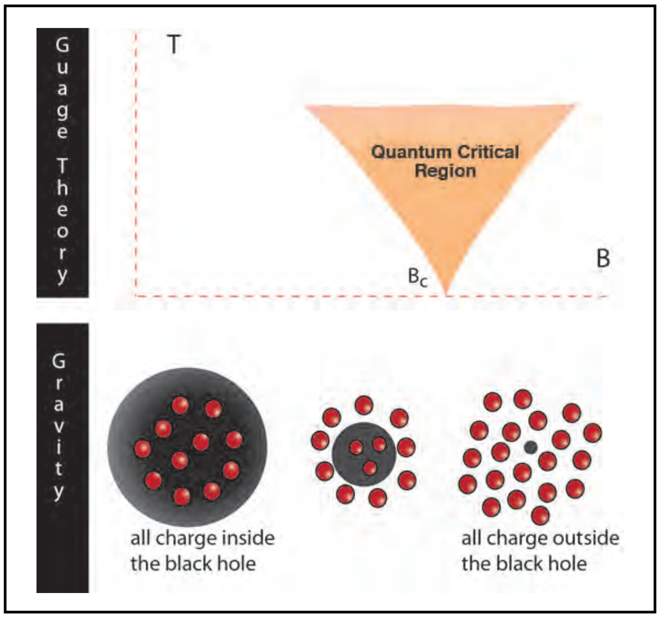
String theorists conjecture that microscopic, vibrating strands of energy are the fundamental building blocks of all matter in the Universe. Says UCLA Professor Eric D'Hoker, "These strings are minuscule: $10_{33}$ cm, or one billionth of one trillionth of one trillionth of a centimeter, and much too small to be seen directly at the LHC. And yet, conjecturing the smallest building blocks of nature to be strings is precisely what has allowed theorists to unite the two grand pillars of 20th century physics, namely quantum mechanics and general relativity. Remarkably, this unification is possible only if space has exactly six extra dimensions."

*String Theory combines the two grand pillars of modern physics, quantum mechanics and general relativity, into a single uni fed theory of the electro-magnetic, weak, strong and gravitational forces of nature.*

Being a theory of quantum gravity, string theory has something to say about black holes. While studying black holes in 1997, Juan Maldacena made a stunning discovery: string theory predicts that a gauge theory (in terms of which the Standard Model of particle physics is formulated) is dual to a theory of gravity, in one extra dimension. Eric comments, "The idea was so brilliant and important that we all instantly dropped what we had been working on at the time, and started testing Maldacena's gauge/gravity duality conjecture." The duality allows physicists to relate physical problems that at first seem to have nothing to do with one another.

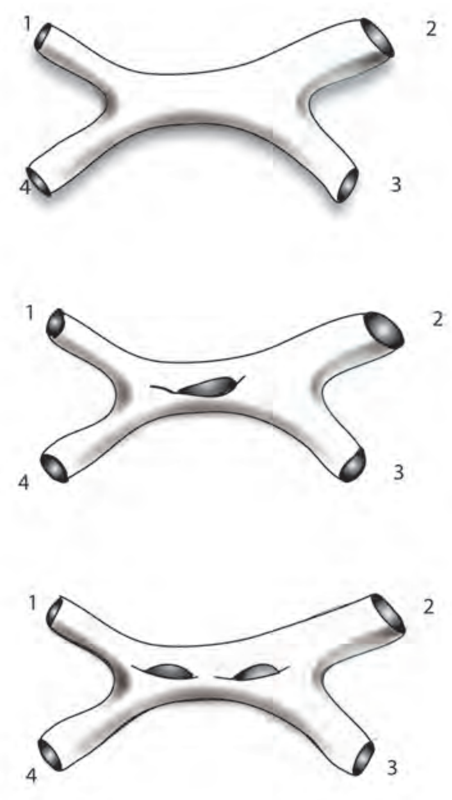
Early in the new millennium, Eric pushed to expand the string theory group at UCLA, leading to the recruitment of two outstanding junior faculty: Professor Per Kraus and Professor Michael Gutperle. The team has flourished ever since, leading an NSF review of their last grant proposal to write: "The group at UCLA has established itself as one of the major groups in String Theory."

Over the past few years, Eric and Per have been using string theory to elucidate thermodynamic and transport properties in a universal class of systems, which involve strongly coupled charged particles, in the presence of magnetic fields. Traditional tools have not produced good solutions at low temperatures and high charge density. The gravity dual of this system involves a magnetic black hole, which carries electric charge, and whose Hawking temperature sets the temperature of the charged matter system. At small magnetic field, the black hole carries all the electric charge, but as the magnetic field is raised, it expels electric charge and shrinks in size. At a critical value $B_c$ of the magnetic field, the black hole will have shrunk to a point. This critical $B_c$ corresponds to a quantum phase transition of the strongly correlated system. Eric recalls, "This discovery was incredibly exciting. In fact, one of the critical exponents we calculated via gravity turned out to precisely match experimental results obtained in Strontium Ruthenates just recently, in 2009."




Eric adds, "Another fascinating direction is being pursued by Michael and Per in collaboration with postdoc Martin Ammon and graduate student Eric Perlmutter. Let me frame their work as follows. Every vibrational mode of a string corresponds to an individual particle in string theory, with its own mass, electric charge, and spin. String theory contains an infinite number of such particles, with higher and higher masses and spins. It is the conspiracy of this infinite number of particles that is responsible for the remarkable properties of string theory, but also for making it highly complex. My colleagues have made progress by focusing on models that contain a manageable subset of these higher spin particle. This has allowed them to address, for the first time quantitatively, questions involving the short distance structure of space-time, and the fate of its causal structure.

Many other aspects of string theory are being studied at UCLA. Eric, Michael and postdoc Marco Chiodaroli are investigating gauge/gravity duals to interfaces, defects, and junctions. Eric and long-time mathematician collaborator Professor D.H. Phong at Columbia University are unraveling the mathematical structure of superstring amplitudes, where strings are viewed as randomly fluctuating surfaces, and diagrams akin to Feynman diagrams play a key role.




## *String Theory*

Central to string theory is the supposition that space has more than three dimensions. At first sight, this idea seems absurd. Our everyday experience of measuring the size of objects by their height, width, and depth appears to leave no room for any dimensions beyond the familiar three. Because the extra dimensions imagined in string theory are curled up into a tiny little space, smaller than atoms and nuclei, their existence has remained hidden from us. In fact, the smaller the size of the extra dimensions, the more energy will be required to detect them experimentally. Can the LHC reach such energies? If yes, the detection of extra dimensions will qualify as one of the most amazing discoveries of all times.

Adding the gauge/gravity duality to the toolbox of the theoretical physicist has made it possible to attack a whole variety of strong coupling problems on which our traditional tools had failed. In particle physics, quark confinement and the collision of heavy ions involve strongly coupled quarks. In condensed matter physics, strongly correlated electrons play a key role in forming exotic phases of matter, such as superconductors with high critical temperature. Through the use of gauge/gravity duality, progress on some of these issues is being made using … gravity and general relativity. And the outcome may be testable in desktop size experiments!

## Zvi Bern, Professor of Physics

Zvi received undergraduate degrees in physics and mathematics from the Massachusetts Institute of Technology and a doctorate in theoretical particle physics from the University of California at
Berkeley. He held positions at the Niels Bohr Institute, Los Alamos National Laboratory and the University of Pittsburgh prior to joining the faculty at UCLA. He is widely known in theoretical physics for research into improved ways of calculating Feynman diagrams without using Feynman diagrams, offering new insights into quantum gravity and into experiments to be carried out at the Large Hadron Collider at CERN. Recently he was co-organizer of a three month workshop at the Kavli Institute forTheoretical Physics at Santa Barbara on recent breakthroughs in our understanding of scattering processes involving elementary particles. He has won a Sloan Foundation Award and an Outstanding Junior Investigator Award from the U.S.
Department of Energy.

## Alexander Kusenko, Professor of Physics

Alexander Kusenko received his undergraduate education at Moscow State University and his graduate education at Stony Brook University where he earned a doctorate. He held a postdoctoral position at the University of Pennsylvania and was a fellow at CERN Theory Division prior to joining the UCLA faculty. He is widely known for his contributions to elementary particle physics, astrophysics and cosmology—in particular, his discovery of non-topological solutions in supersymmetry, his work on the physics of the early universe, his theories of neutrinos and their applications to astrophysics, and his investigations into cosmic rays and gamma rays. Alex serves as Senior Scientist at the Institute for Physics and Mathematics of the Universe in Japan; he is a Fellow of the American Physical Society; and he is an active member of the Aspen Center for Physics.

## Eric D'Hoker, Professor of Physics

Eric was an undergraduate at the Ecole Polytechnique in France and received his doctorate in physics from Princeton University. He was a postdoc at MIT and held faculty positions at both Columbia and Princeton universities prior to joining the faculty at UCLA. He has held many visiting positions, including the Freeman Dyson Distinguished Visiting Professorship at the Princeton Institute for Advanced Study. His principal research interest is in theoretical particle physics and mathematical physics, specifically supersymmetric gauge theories, supergravity and superstring theory. He is widely known for his work on superstring perturbation theory and AdS/CFT. He has also worked on topics in pure mathematics and condensed matter physics. Eric served as President of the Aspen Center of Physics and is presently Honorary Trustee. He received the Department's Outstanding Teaching award 15 times and currently serves as Vice Chair for Academic Affairs.

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Tompkins Ph.D., John Carter
Tomren, Douglas Roy
Topper, Jeffrey
Toy, Andrew Moon
Trippe Ph.D., Thomas Gordon
Tse Ph.D., Egbert Sau-Nam
Turk Ph.D., Theresa G.
Turnbach Ph.D., Susan Elizabeth
Uchizono, Shiro Alfred
Villanueva, Edward Vincent
Visher, Rex Alexander
Wagner, Tim
Walsh, Eryn Corralejo
Wang, Aileen
Wang Ph.D., Zhengzhi
Webster Ph.D., Emilia Herescu
Weitzman, Marie A.
Weyl Ph.D., Guy Michael
Wilson, David E.
Wilson, Wendy Savitt
Woo, Charles Chak
Wright Ph.D., Byron T.
Wuerker, Ralph F.
Xu, Wenqin
Yoon, Un Ju
Zuppan-Hood, Patricia Jude

## Current Use Funds

**Astronomy Colloquium Fund**

**Gordon M. Binder Postdoctoral Fund**

**Chair's Discretionary Fund**
The Ahmanson Foundation
Scheifele-Holmes Family Foundation
Ralph F. Wuerker
Multiple Donors

**Condensed Matter Physics Experiment Research Fund**
Anonymous

**John Engel Graduate Fellowship Award Fund**
Agnes Lucille Engel Trust

**Andrea Ghez/Evan Frankel Foundation**

**Andrea Ghez Research Fund**
The Boeing Company
Lauren B. Leichtman and Arthur E. Levine
Janet Marott
Timothy Pope

**Graduate Colloquium Fund**
Howard & Astrid Preston

**Michael & Gretchen Kriss Teaching Assistant Award**
Michael & Gretchen Kriss

**Arthur E. Levine & Lauren B. Leichtman Fund in Astrophysics**
Arthur E. Levine & Lauren B. Leichtman

**Dr. Waldo Lyon Scholarship Fund in Physics**
La Vonne M. Bloom Trust

**Janet Marott Student Travel Awards**
Janet Marott

**Physics Alumni Graduate Fellowship**
Alliance Bernstein Holding LP
Brian Brugman

**Physics & Astronomy Alumni Alliance**
Robert Baker
Harold Baran
John Gordon Coffer
Daniel Lewis Dawes
Aaron James Heick
Takeo Theodore Hirai
Roland Paul Michaelis
Erno H. Ross

**Physics & Astronomy Capital Donations**
Anthony Armini
Ben Holmes
Michael & Gretchen Kriss
Howard & Astrid Preston
Charles C. Woo

**Physics & Astronomy Instruction**

**Physics Solid State Research Group Fund**

**Howard Preston Fund**
Howard & Astrid Preston

**Preston Research Fund**
Howard & Astrid Preston

**Seth Putterman Group Fund**
Elwood & Stephanie Norris Foundation

**Regental Discretionary Fund**
Amperics, Inc.
Anonymous
Asylum Research
Bank of America
Elliott Hinkes
National Physical Science Consortium
Wesley Ann Norton
Whitehall Foundation Inc.

**David Saxon Physics Graduate Fellowship Fund**
Barbara Saxon
Shirley G. Saxon

**Robert L. & Jane Schneider Physics & Astronomy Graduate Award**
Robert & Jane Schneider

**Space Physics Center Discretionary Fund**

**Charles Whitten Jr. Memorial Fund**
Multiple Donors

**Winstein/Holmes Graduate Student Support Fund**

**Eugene Y. Wong Physics Graduate Fellowship**
Dorothy Pan Wong

# Endowments

**John Mead Adams Memorial Fund**
Mrs. John Adams

**Alyne and Leon Camp Graduate Fellowship**
Alyne & Leon Camp

**John Dawson Memorial Fund**
Theragenics Corporation

**Leo P. Delsasso Fellowship in Physics**
Mary Mussen Delsasso Estate

**Delsasso Fund**
Leo & Mary Delsasso

**Robert Finkelstein Fellowship in Theoretical Physics**
Robert & Norma Finkelstein

**Enrichetta, Beverly, and Anthony Gangi Endowed Scholarship Fund**
Anthony & Beverly Gangi

**Lauren B. Leichtman and Arthur E. Levine Astrophysics Endowed Chair**
Leichtman & Levine Family Foundation

**Dr. Waldo Lyon Scholarship Fund in Physics**
La Vonne M. Bloom Trust

**Richard B. Kaplan Endowed Graduate Award in Astrophysics**
Richard Kaplan & Rosamond Westmoreland

**Preston Family Endowed Graduate Fellowship in Astrophysics**
Howard & Astrid Preston

**Physics Endowment Fund**
Multiple Donors

**Physics Alumni Summer Undergraduate Research Fellowship**
Multiple Donors

**J. Reginald Richardson Fund**
Louise F. Richardson

**Rudnick-Abelmann Endowed Fund**
Ron & Jeryl Abelmann
Marty Barmatz
Joseph Heiserman
Richard B. Kaplan
Reynold Shigeru Kagiwada
Moises Levy
Myron A. Mann
John Marcus
James Susumi Imai
Richard Stern
Taylor Wang
Yi Ying Wu

**David S. Saxon Presidential Chair Fund in Physics**
Multiple Donors

**David S. Saxon Presidential Chair Fund in Mathematics and Physics**
Multiple Donors

**Dr. Bruce and Joan Winstein Endowment**
William Layton
Bruce Winstein

# Leaders in Philanthropy

The Department of Physics & Astronomy is deeply grateful for our invaluable philanthropic partnerships with alumni and friends who share our passion for scientific research and education. It is the philanthropic vision of these individuals, as well as that of foundations and corporations, that enable the Department to remain at the cutting edge of innovation and discovery. Every gift – large or small – makes a huge impact on our work and our teaching. Below, we would like to share some insights into what drives our philanthropic leaders to give so generously. Thank you for your support.

Left - Right: Arthur Levine and Lauren Leichtman, Andrea Ghez and Chancellor Block, Michael Kriss, Andrea Ghez with Janet Marott and graduate students Sylvana Yelda and Breann Sitarski.

*phi·lan·thro·py:*
*is the effort or inclination to increase the well being of humankind.*

## Ron and Jeryl Abelmann

*"My 5 ½ years in the UCLA Physics department provided me with the platform for my professional life. I not only got to enjoy the experience of learning some of the fundamental truths of physical science, but just as important, I learned how to think both logically and creatively. During that time, I had to work at least 20 hours a week in order to pursue my physics education and still live a reasonably active university life. Those years were perhaps some of the most fulfilling of my life.*

*In honor of the late Professor Isadore Rudnick, with whom I worked for my master's degree, and for whose constant guidance and encouragement I will always be grateful, I established the Rudnick-Abelmann Scholarship Fund.*

*My goal was to provide the necessary financial support for worthy physics students at both the undergraduate and graduate levels, to allow them to continue their studies unimpeded by financial constraints. There is no better feeling for me than to read letters from awardees underscoring the importance of these funds in allowing them to continue their studies. It's wonderful to know that the scholarship fund has had such an important impact on the lives of so many students. And I thank UCLA for the opportunity."*

Ron has been the architect behind the Rudnick-Abelmann Scholarship, which has provided more than 30 need-based scholarships to undergraduates and graduates since the scholarship was established in 1998. Ron and Jeryl have been supporting the department since 1991, and make time to visit campus at least once a year. Ron graduated with a B.S. in physics in 1959 and an M.S. in applied physics in 1960, before completing his MBA at Stanford. His successful career in industry included leadership roles at a number of technology companies based in Silicon Valley. His most recent positions were President and CEO of Wind River Systems; and Chairman of Logilent Learning Systems. Ron currently serves on the Board of Directors of several high-technology public and private companies.

## Ben and Carol Holmes

*"My entire professional career centered on technology. My applied physics degree from UCLA prepared me in the fundamentals of science, and it also prepared me to deal with the rapid changes in technology in the last quarter of the century. The liberal arts courses I took at UCLA helped round out my education. When I look back at many of my accomplishments, they were a direct result of my time at UCLA. I was also blessed to meet a great many acquaintances there, many who remain my closest friends. How can one not feel an obligation to pay back an institution that had such an impact on your life? In many ways it is because of UCLA that my wife and I are in a position to make a modest contribution to allow the institution to continue its mission. It is the least we can do."*

Ben received his B.S. in physics in 1959, his MBA from USC in 1966, and went on to have a successful career at Hewlett Packard, serving in a number of executive roles before starting the Holmes Company, a firm that specializes in healthcare consulting with an emphasis on the medical device industry. Ben and Carol have been supporting UCLA since 1972. They have emerged as philanthropic leaders, providing a significant capital contribution to name the Ben Holmes Auditorium on the first floor of the Physics & Astronomy building, in addition to helping support the Bruce & Joan Winstein endowment through a matching gift contribution. Ben has expressed an interest in supporting graduate students and looks forward to future contributions. Ben is a member of the Physical Sciences Board of Visitors.

## Richard B. Kaplan

*Discretionary support*

*"I graduated with an M.S. in physics in 1962 and went immediately into a career in high temperature metallurgy. During my 50-year career, I invented a revolutionary material used in artificial joints that have been successfully implanted in hundreds of thousands of patients. My company also developed a metal composite used for boosting satellites into high earth orbit. When I reflect on my career, I realize that it was my education in physics that gave me the tools to be able to talk to other scientists and understand their needs.*

*I started giving to the UCLA physics department as a way of saying thanks, belatedly, to the professors and graduate students who aided me in so many ways. Today, with budget cuts and not enough emphasis on the hard sciences, I see my donations as crucial for helping the department stay competitive and at the cutting edge of science."*

*Astrophysics*
*"From an early age, I wondered about the universe - where it came from, how large it is, where we are headed. . . After earning my degree, I went from fission to fusion to space exploration, playing minor but important roles in very large projects. My fingerprints are on probes that continue to travel billions of miles into space. Men and women in astrophysics and astronomy have made fabulous discoveries in the last 50 years, but the big questions of time and space are still a mystery. By funding an endowed graduate award in astrophysics, I feel I am sending out my own time capsule, and that in some distant future one of the bright UCLA astrophysicists will be able to answer the questions, 'Where did we come from?' and 'Where are we going?' In some way, I will be there to share in the delight when the answers to those questions are discovered."*

Richard has been supporting the department since 1981 in several ways. Last year he made significant contributions to the Rudnick-Abelmann Scholarship, and helped the department secure a matching gift challenge. He recently established the Richard B. Kaplan Endowed Graduate Award in Astrophysics to help support students working with Professor Alice Shapley. Richard is the President of Ultramet, a company that develops and manufactures refractory metals, platinum group metals, and ceramics for demanding applications that meet the needs of the aerospace, defense, biomedical, and energy industries.

## Michael and Gretchen Kriss

*"Providing support for UCLA and in particular to the Department of Physics and Astronomy is simply a way of repaying the debt that my family and I owe to a great university, one that provided me with an education that has lasted a lifetime in corporate and academic research. In these difficult times, when budget cuts and rising costs are squeezing UCLA and the Department of Physics and Astronomy, it is important to make contributions that have the greatest impact on the students and faculty. Currently my wife and I are supporting the Michael & Gretchen Kriss Student Teaching Assistant Awards, based on the needs established by the department three years ago. In the near future, we will again work with the department to address the greatest needs of the students and faculty, and based on those discussions choose the best way to continue to support their efforts to advance the frontiers of science and ensure that our society will be well served by bright and enthusiastic men and women from UCLA. For my wife and me, supporting the Department of Physics and Astronomy has been a privilege and honor, and we take considerable pride in the faculty and students who continue to have an impact on our collective well being."*

Michael and Gretchen Kriss have been steadfast supporters of the department since 1969. They established the Michael & Gretchen Kriss Student Teaching Assistant Awards in 2009 to help support the research and teaching efforts of teaching assistants. Michael received his B.A. in physics in 1962, his M.A. in 1964, and his Ph.D. in physics in 1962. He worked at Eastman Kodak Research Laboratories for several years, served on the faculty at the University of Rochester, and is currently President of MAK Consultants, a firm that focuses on wide-range color-imaging problems. Michael is also a member of the Physical Sciences Board of Visitors.

## Janet Marott

*"UCLA has been a focus of my support since I graduated - I wanted others to be able to share in the world's finest educational experience. Although chemistry was my major, astronomy is my muse. I find that study of the cosmos stimulates both the mind and the spirit. Recently, UCLA afforded me the opportunity to visit the largest telescope in the world, the Keck. Even though technology allows use of this amazing instrument remotely, I wanted students to be able to experience the grandeur of seeing this great instrument in person, so I established a student travel awards fund to make this possible."*

Janet established the Janet Marott Student Travel Awards in 2010, which so far has supported three students to travel to the Keck telescope for their graduate research, with more students slated to benefit from this tremendous opportunity next year. Janet has been supporting areas all across UCLA since 1970, and is currently a member of the South Bay Alumni Association, Women & Philanthropy and the Physical Sciences Board of Visitors. She had an extensive career in information technology at Boeing and at Carter Hawley Hale Information Services, and is now enjoying retirement.

## Howard and Astrid Preston

*"I've always felt that my experience at UCLA was an essential factor in my success; providing support to the department is both a reflection of that contribution and also an indication of my continuing interest in the department's growth. In recognition of the many distinguished research accomplishments of Professor Ghez, her leadership of the Galactic Center Group, and the exemplary mentoring she's given to her graduate students, Astrid and I established an endowed graduate fellowship. We look forward to seeing the department continue to build upon its impressive accomplishments."*

Howard completed his B.S. in physics in 1965, and his Ph.D. in 1974. He has been supporting the department since 1981 in a number of areas, including the Astronomy Graduate Colloquium, and served as a major contributor during the capital campaign. He and his wife, Astrid, also a UCLA graduate (in English), contribute in a variety of areas across campus. Astrid is a member of Women & Philanthropy, and Howard is a member of the Physical Sciences Board of Visitors. Howard and Astrid recently established the Preston Family Endowed Graduate Fellowship to support the work of Professor Andrea Ghez and the Galactic Center Group.

## Ralph Wuerker

*"In spite of recent government stimulation efforts, physics has declined in popularity in our country due to a lack of job opportunities. For example, physics departments at several state colleges in Texas are in the process of closing due to low enrollments. To counteract these trends I support physics at UCLA. However, I earmark my contributions to projects that I believe are important or in need of encouragement."*

Ralph is a great friend to the department who has been providing discretionary support since 2008. His generosity allows the Department Chair to meet financial needs as they arise to support students, faculty, and facility improvements. Ralph has had an extensive career as a defense contractor working at GRW and as the Associate Director of the HIPAS (High Power Auroral Stimulation) Laboratory, a focused laser beam project within the UCLA Plasma Physics Lab. He is passionate about improving K-12 science education, and enjoys sharing his enthusiasm for science with others.

## Elwood Norris

*"It is a pleasure for me to lend financial support to Professor Seth Putterman and his team in the physics department of UCLA, first and foremost because of the amazing work they do on so many different projects. I have always been supportive of efforts dealing with new and innovative technologies, and in my opinion Professor Putterman and his team embody the best qualities geared towards moving us forward in those areas."*

Elwood Norris, also known as "Woody," has been a friend to the Department of Physics and Astronomy since 2005, with significant annual contributions to Seth Putterman's research group. Professor Putterman met Woody after he was featured on a scientific education show, and asked Woody to come and speak to his students. Their professional relationship has continued to flourish over the years, and Woody remains a fan of the work of Professor Putterman and his research team. Woody holds over 100 patents worldwide and is noted for winning the Lemelson-MIT Prize for Inventors in 2005. Woody continues to support scientific projects through the Elwood and Stephanie Norris Foundation.

## Arthur Levine and Lauren Leichtman

Arthur and Lauren are among UCLA's most loyal supporters, having given to initiatives all across campus, including medicine, athletics, and entrepreneurship, since 1986. Arthur received a B.A. in philosophy in 1973 from UCLA, and his MBA in 1976 from the UCLA Anderson School of Management, before completing his J.D. at Columbia University in 1982. Lauren received a psychology degree from Cal State Northridge before completing her J.D. at Southwestern School of Law, followed by her LLM at Columbia University School of Law. Arthur and Lauren founded Levine Leichtman Capital Partners (LLCP) in 1984. Arthur's deep-seated passion for understanding the origins of our universe led to his discovery of Professor Andrea Ghez's work in 2005; shortly afterwards the couple established the Lauren B. Leichtman & Arthur E. Levine Astrophysics Endowed Chair, held by Professor Ghez. In addition to the establishment of this chair, Arthur and Lauren have been contributing annually to Professor Ghez's Galactic Center Group, to ensure the long term sustainability of her research team. Arthur is also a member of the Physical Sciences Board of Visitors.




Left to Right: Howard and Astrid Preston, Ben and Carol Holmes, Carol and Bob Schneider with the Joe Bruin.

## *Robert and Jane Schneider*

Robert and Jane Schneider are very loyal Bruins, most recently demonstrating their support by establishing the Robert L. and Jane Schneider Physics and Astronomy Graduate Award, which supports graduate students within the Department of Physics & Astronomy. Bob graduated from UCLA in August 1956 with a bachelor's degree in applied physics. He continued his education at Cal State Fullerton where he received an MBA, although he remained a scientist at heart. Bob and Jane met shortly after he graduated from UCLA, when they were both working at North American Aviation – he as an engineer and she as a secretary. Their romance bloomed, and they are about to celebrate their 50th wedding anniversary. Bob had a long and successful career, and retired from Boeing as a Principal Engineering Specialist in 1999. He and Jane enjoy traveling, playing golf, bowling, hiking, and attending events at UCLA and performances of the OC Symphony.

Bob has long been an advocate of "taking UCLA on the road" and held the position of president of the Orange County Bruins from 1982 to 1984. Bob and Jane are season ticket football holders and never miss an opportunity to attend a game. They have participated in the Chancellor's Associates membership society for several years, and recently their enthusiasm for the Department has grown. They have attended numerous events showcasing our esteemed faculty and their research.

## *John Wagner*

John earned three UCLA degrees: a B.S. in physics in 1980, an M.S. in physics in 1983, and an M.S. in Electrical Engineering in 1985. John is the Founder, Managing Partner, and Senior Portfolio Manager at Camden Asset Management. As member of the Board of Trustees at the Ahmanson Foundation, John has made significant contributions to the Chair's Discretionary Fund, which has enabled the department to fund many projects, including helping to improve undergraduate teaching labs. John has been a supporter of UCLA since the late 1990s, donating in a variety of areas on campus, including athletics, medicine and engineering.


Left top : Howard Preston, Roberto Peccei, Richard Kaplan, plaque commemorating the generous donation from the Preston family for the Astronomy Reading Room. Ben Holmes holding a framed copy of the plaque honoring Mr Holmes for his generous donation for Ben L. Holmes Auditorium.
Bottom Left: John Wagner, Elwood "Woody" Norris, Ralph Wuerker and Ron Abelmann.

## In Memory of Bruce Winstein

Bruce Winstein

Longtime supporter Bruce Winstein passed away on February 28, 2011. Bruce and his wife, Joan, established the Bruce and Joan Winstein Endowment with significant matching contributions from Ben Holmes and William Layton. The endowment supports students within the department with a particular emphasis on undergraduates. Bruce graduated with a B.S. in physics from UCLA in 1965 and received his Ph.D. from Cal Tech in 1970. He had a long and distinguished career in academia, holding a faculty position in physics at the University of Chicago, where he focused on cosmology. During the last 10 years of his life, Bruce was the co-leader of a large, multi-university collaboration searching for gravitational waves from the "big bang." Before entering the field of cosmology, Bruce was one of the world's most influential experimental physicists working on fundamental particles. He led the team that discovered "direct CP violation," i.e. the violation of a long-cherished symmetry property of fundamental particles.

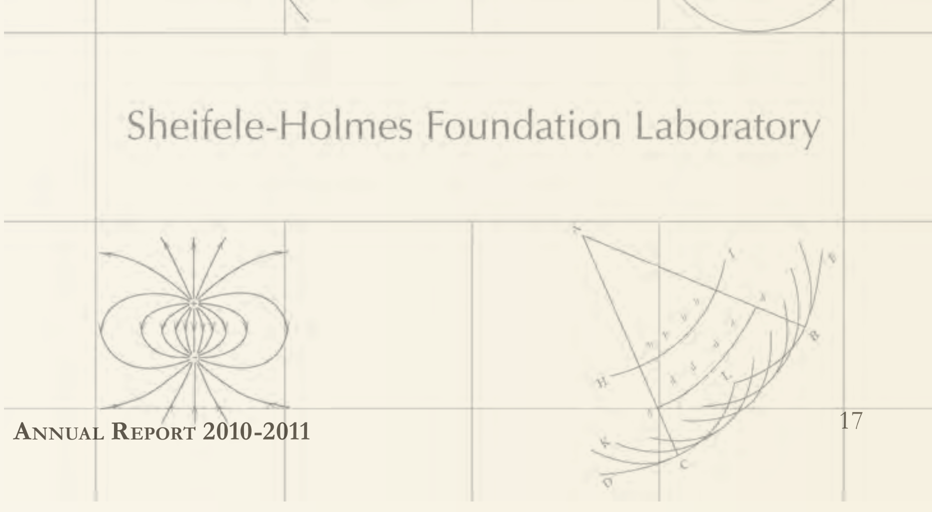
Bruce influenced his professional colleagues through his teaching and his community leadership as well as through his research, and his legacy lives on within the Department of Physics and Astronomy. In fact, the Winstein family name is well known at UCLA, as his father Saul was a distinguished faculty member within the Department of Chemistry & Biochemistry, and his mother Sylvia has provided significant support to chemistry and the arts at UCLA.

## In Memory of Eliot Hinkes

Dr. Eliot Hinkes passed away in November, 2009. He came to UCLA in 1970, undertaking a fellowship in Hematology and Oncology at the David Geffen School of Medicine. Dr. Hinkes had a 30-year career in private practice in Los Angeles and served as Associate Professor in Hematology and Oncology at the School of Medicine until his retirement. Dr. Hinkes was passionate about astronomy and collected rare books in the subject. He took astronomy classes at UCLA and became fascinated with Professor Andrea Ghez's research on black holes and the galactic center. His contributions to her research have had a significant impact.

## In Memory of Anthony Gangi

Anthony Gangi, Professor Emeritus in Geology & Geophysics at Texas A&M University, passed away in October of 2011. Professor Gangi received his B.S. in physics in 1953, his M.S. in 1954, and his Ph.D. in 1960, all from UCLA. His area of research was theoretical geophysics, with a particular focus in seismology. During the spring of 2011, Professor Gangi began discussions with the UCLA Office of Planned Giving to establish the Enrichetta, Beverly, and Anthony Gangi Endowed Scholarship Fund ("Gangi Scholarship Fund") to support meritorious students within the Department of Physics & Astronomy. Since Professor Gangi's passing, his widow, Beverly Gangi has also made significant contributions to the department. Professor Gangi made his first gift to UCLA and the Department of Physics &Astronomy in 1981, and his philanthropic contributions continued throughout his lifetime. In a conversation with Dean Joseph Rudnick and Department Chair Jamie Rosenzweig, Professor Gangi expressed fond memories of the Department and particularly the Institute of Geophysics & Planetary Physics, adding that he was delighted to have the opportunity to give back to an institution that shaped his academic career.



# Infrared Laboratory Group

Ian McLean, James Larkin and Mike Fitzgerald

Now in its 22nd year, the Infrared Lab at UCLA has played a key role in the development of state-of-the-art astronomical instruments which enable a broad range of science on multiple telescopes. For example, all of the currently operational infrared (IR) instruments for the huge 10-m telescopes of the W. M. Keck Observatory (NIRSPEC, NIRC2 and OSIRIS) were provided either wholly or in part from the IR Lab; Caltech led the NIRC2 project but the detectors and software came from UCLA. In addition, two test cameras (KCam and SHARC) were delivered to enable first light of the Keck Adaptive Optics (AO) systems. AO systems provide real-time compensation of atmospheric turbulence. This equipment has provided a powerful recruitment advantage for UCLA.

Today, the IR Lab has several large projects nearing completion. MOSFIRE is a multi-object spectrograph for infrared exploration (PI: McLean). It is a large, vacuum-cryogenic instrument for the Keck Observatory that allows up to 46 objects, such as faint distant galaxies, to be recorded simultaneously. Also nearly complete is the integral field spectrograph for the Gemini Planet Imager (GPI), which is a powerful adaptive optics system capable of directly imaging planets around nearby stars (PI: Larkin). GPI is being built for the 8-m telescope in Chile called Gemini South. Finally, the IR Lab is also constructing FLITECAM for NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) and developing the design for IRIS, a first instrument for the proposed 30-meter telescope (TMT). These projects are led by professors McLean and Larkin respectively. Consequently, this has been an exciting year for the IR Lab. On July 1, 2010 MOSFIRE achieved "first light" in the Lab, meaning that this was the first time light had passed through the almost-completed instrument. Testing continued all year and shipping of the instrument to the 14,000ft summit of Mauna Kea in Hawaii is planned for early 2012. Meanwhile, the integral field spectrometer (IFS) for the GPI also achieved first light in the Lab and should be ready to integrate with the rest of the system at UC Santa Cruz in late 2011. Both MOSFIRE and GPI are technically challenging in different ways and both are good examples of successful collaborations among multiple organizations. Meeting NASA's request to accelerate delivery of FLITECAM to fill a gap in the SOFIA schedule was another (unexpected) challenge. However, the instrument was ready for delivery to NASA by late June 2011.

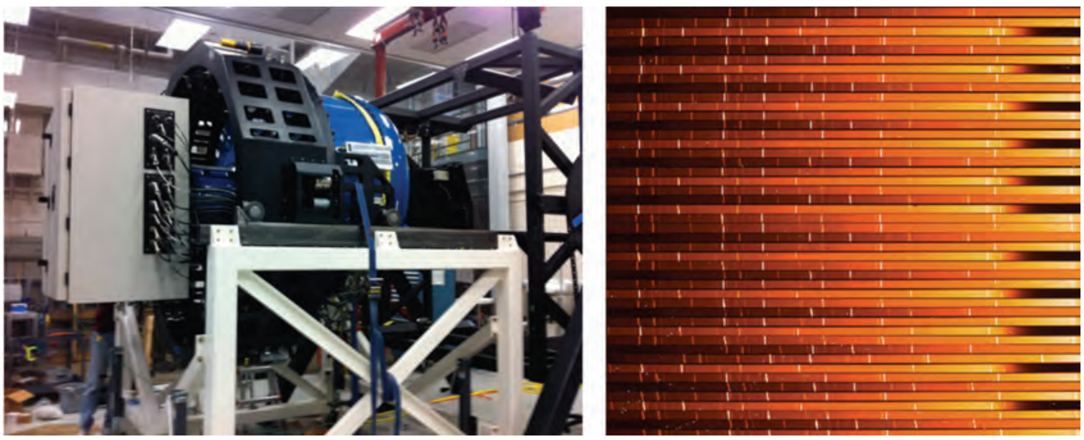


Figure 1: MOSFIRE: The picture on the left shows the completed instrument on its handling frame. On the right is a multi-object infrared spectrum using a regular pattern of slits and a neon arc lamp to generate emission lines

Interestingly, GPI is led by Bruce Macintosh (Lawrence Livermore), the lab's first graduate student (UCLA 1995). It combines an advanced adaptive system, a shearing interferometer and an integral field spectrograph. The goal is to achieve contrasts of 100,000,000:1 compared to the central star in order to survey the outer solar systems of more than 100 young stars. GPI will be able to identify young Jovian planets at comparable separations as Jupiter and Saturn to the Sun, allowing us for the first time to discover large numbers of planetary systems with architectures like our own. James Larkin at UCLA has led the design and construction of the spectrograph. It takes more than 40,000 spectra simultaneously over a square field of view and reassembles them into 18 images at different wavelengths. The simultaneity of the images is critical since it freezes all of the optical effects from the atmosphere and the adaptive optics system. Using the variation in behavior between optical artifacts (speckles) and true planets, it produces another factor of 10—100 in contrast improvement very close to the stellar image itself. First light for GPI in Chile is eagerly anticipated in May or June, 2012.

Starting in September, 2011 we began a phase of prototyping difficult components for the IRIS spectrograph which is one of three "first light" instruments being developed for the TMT. This will be the largest instrument the lab has ever built, with delivery as far off as 2020. We also participated in the Call for White for Papers

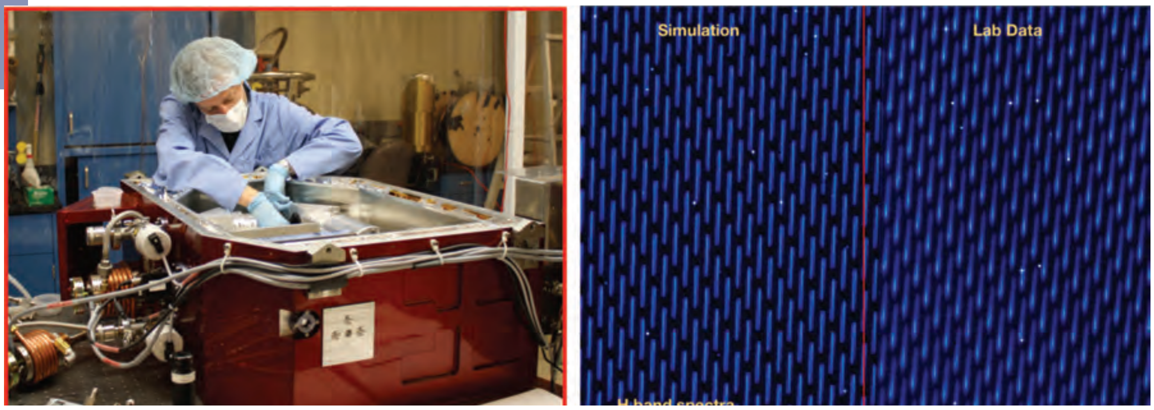



Figure 2: The picture on the left shows the IFS for GPI during integration and testing. On the right is an infrared integral field image obtained in the lab during testing compared to a simulation.

Keck instruments by proposing upgrades to NIRC2 (Fitzgerald), OSIRIS (Larkin) and NIRSPEC (McLean). During 2011 we also worked on two new proposals. One is an integral field spectrograph for a proposed Next Generation Adaptive Optics (NGAO) system for Keck, and the other is a high-resolution imaging spectropolarimeter (HYSPI) for SOFIA.

**Ian McLean** has continued as IR Lab Director and Associate Director for the University of California Observatories (UCO), in addition to his leadership of the MOSFIRE and FLITECAM projects. He supports graduate students Kristin Kulas and Gregory Mace, and his research includes the detection and study of the coolest sub-stellar objects known as brown dwarfs, as well as infrared spectroscopy of high redshift galaxies.

The primary research of **James Larkin** focuses on the early development of galaxies like our own Milky Way. Using his instrument OSIRIS at the Keck Telescopes, he and his former graduate student Shelley Wright (now a faculty member at University of Toronto) measure the internal motions of galaxies more than 9 billion light years away at a time soon after their formation. A major goal of this research is to learn when and how these vast structures began to mature into the stable rotating disk galaxies we see in the Universe today. As a by-product of these measurements they are also able to identify black holes growing at the galaxy centers and can measure the composition of the gas going into the early generations of stars. Larkin's effort to construct the Gemini Planet Imager spectrograph has been assisted by graduate student Jeffrey Chilcote.

**Mike Fitzgerald** joined the group in July 2010 after completing his Michelson Fellowship at the Lawrence Livermore National Lab. The relationship between exoplanets and dusty circumstellar debris disks, which act as tracers of planet formation processes, remains a prominent target of his research. Fitzgerald will continue to apply the NIRC2 camera and the Keck AO system to search for faint emission from planets and disks around nearby stars, and will be developing similar techniques for the Gemini Planet Imager. He has worked with graduate students Jeffrey Chilcote and Thomas Esposito to develop and apply high-contrast imaging techniques to these systems. In 2011, Fitzgerald and other members of the GPI science team successfully proposed to use the instrument in a large survey of nearby stars for extrasolar planets and debris disks. The team was awarded 890 hours of observing time for use over the next several years. Fitzgerald will be leading the portion of the Gemini Planet Imager Exoplanet Survey dedicated to detecting and characterizing polarized light from circumstellar debris disks.

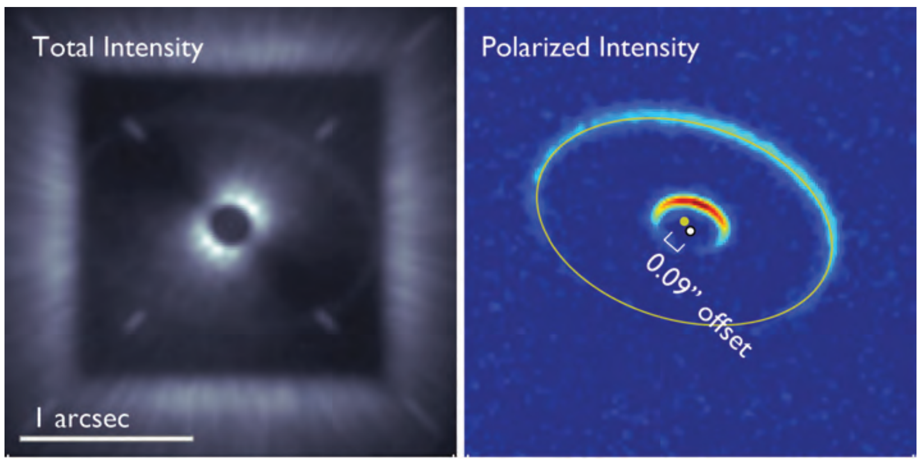



Figure 3: On the left is the response of the Gemini Planet Imager to light from a nearby star. The action of the adaptive optics system is to create a square region of high contrast where faint material and objects can be detected. In this case light from the star dominates. On the right is the same scene as detected in linearly polarized light. In this case light scattered from two circumstellar debris rings is easily detected. Offsets of ring centers from the stellar location indicate the action of a perturbing body.

# Institute for Planets and Exoplanets (iPLEX)

## David Jewitt

The Institute for Planets and Exoplanets (iPLEX) is a new endeavor between faculty members in the Departments of Earth and Space Sciences, Physics and Astronomy and Atmospheric and Oceanic Sciences. The principal aim of iPLEX is to enhance the profiles of UCLA scientific research into the study of the solar system, on the one hand, and of planets around other stars (exoplanets), on the other.

This is a propitious time for the science of planets, the total known number of which is fast approaching 1000. All but eight of these planets orbit stars other than the sun. A major theme of iPLEX is to develop detailed knowledge from the ongoing study of the solar system and apply it to the more distant planetary systems about which detailed physical information will always be comparatively sparse. In turn, the astronomical study of remote planetary systems will provide an invaluable context for understanding our own place in the universe.

iPLEX will promote scientific interaction between researchers working on related fields, and will improve the visibility of UCLA research across campus, into the community and throughout the country. On the longer-term, these efforts will help UCLA to attract the best graduate students, postdocs and other researchers to work on one of the hottest topics in modern science and provide a focal point for interest in science at UCLA.

Seed money for iPLEX has been generously provided by **Joe Rudnick (Dean of Physical Sciences)** and **James Economou (Vice Chancellor for Research).** Associated Physics and Astronomy faculty members include **Mike Fitzgerald, Brad Hansen, David Jewitt, Mike Jura, Jean-Luc Margot and Ben Zuckerman.**

Gas giant planet Jupiter, largest planet in the solar system at 310 Earth Masses and prototype for gas giants around other stars. Images from the Cassini Spacecraft (NASA/JPL/University of Arizona).

# Extrasolar Planetary Systems:

## Michael Jura

Using data acquired with the 10m Keck telescope in Hawaii, **Beth Klein** completed her Ph.D. on the composition of extrasolar asteroids -- the building blocks of rocky planets. The most important result is that these asteroids are largely composed of the same four elements–oxygen, magnesium, silicon and iron–that are the dominant constituents of Earth.

"It is clear that extrasolar planetary systems produce rocky bodies that are compositionally similar to terrestrial planets in our own solar system. Earth-like planets apparently do form elsewhere in the galaxy," Klein's group write in their Astrophysical Journal paper. (*http://arxiv.org/pdf/1108.1565* ) *Rocky Extrasolar Planetary Compositions Derived from Externally-Polluted White Dwarfs*

Image: An asteroid getting shredded by a white dwarf's tidal forces

# Solar System Astronomy

## Jean Luc Margot

Research efforts in our group center on describing planetary interior properties and processes from high-precision measurements of spin and orbital dynamics. We rely on a combination of telescopic andspacecraft data at wavelengths ranging from optical to radio.

In the past year, **Julia Fang** has published the first fully dynamical orbital solutions to triple asteroid systems, yielding measurements of component masses and densities, as well as insights into formation and evolution processes. This work will continue with additional observations at Keck.

Several lines of evidence indicate that Europa has a liquid water ocean under its icy crust. "Because of this ocean's potential suitability for life, Europa is one of the most important targets in all of planetary science." NRC Planetary Decadal Survey 2011
Image credit: "NASA's Galileo mission"

Using the Goldstone and Green Bank Telescopes, **Jean-Luc Margot** is measuring the spin states of Mercury, Venus, Europa, and Ganymede. The data show that Mercury has an outer molten core and that Venus exhibits length-of-day variations. The amplitude of oscillations in the spin of the Galilean satellites is strongly dependent on the thickness and rheology of their icy shell, perhaps the most important determinants of their astrobiological potential. Europa's obliquity may explain remarkable surface features, such as the distribution and shape of cycloids, and the direction of strike-slip faults.

# Astrophysics

## Brad Hansen

**Ian Crossfield,** along with his advisor **Brad Hansen,** and collaborator **Travis Barman,** of Lowell Observatory, published spectroscopic constraints on the atmospheric composition of the super-earth planet GJ1214b. Using the NIRSPEC instrument on the Keck telescope, they demonstrated that the atmosphere of this planet must be poor in methane, relative to a normal chemical composition atmosphere, as had been previously claimed for this planet.

Brad Hansen, in collaboration with Norman Murray at the Canadian Center for Theoretical Astrophysics, has demonstrated that their models can explain the distribution of mass and angular momentum in many recently discovered planetary systems around nearby stars. This is in contrast to previous models, which were designed to explain more massive planets and whose predictions fail for the lower mass systems now being uncovered. The new models also provide a new explanation for the properties of observed, Neptune-mass planets in short period orbits -- as a form of truncated Jupiter-mass planets, instead of real, ice-rich Neptune analogs.

# Wide-field Infrared Survey Explorer (WISE)

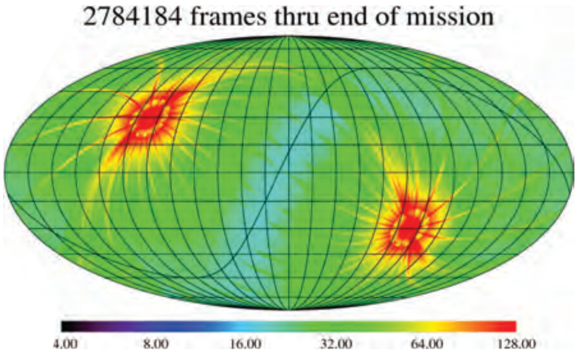
## Edward (Ned) L. Wright

**Ned Wright** has been very busy with the Wide-field Infrared Survey Explorer (WISE). WISE stopped observing on February 1, 2011, but the data analysis continues at full speed. The preliminary data release covering 57% of the sky was released to the public on April 14, 2011, and the final data release of the whole sky is scheduled for spring of 2012. The catalog should have over 600 million sources, primarily galaxies with redshifts 0 to 1.

Particularly noteworthy results are the observation of over 155,000 asteroids of which over 32,000 are new discoveries, observation of over 500 Near Earth Objects with over 130 new discoveries; the discovery and confirmation of over 100 new brown dwarf stars including a new spectral class, the Y dwarfs, which range down in temperature to 300 K; and the discovery of infrared luminous galaxies with luminosities ranging to over 100 trillion Suns.

Every asteroid observed by WISE gets its size determined by a radiometric diameter measurement. Using these diameters, WISE has been able to show that the goal of finding over 90% of all the potential civilization ending NEOs bigger than 1 km diameter has been met, and that the number of potential city busting NEOs bigger than 140 meter diameter is smaller than had been feared, but most of these smaller objects have yet to be found. WISE discovered the first known Trojan asteroid resonantly locked to the Earth's motion around the Sun. Luckily none of the

How much of the sky did WISE see?



known NEOs is likely to hit the Earth in the next century, but continued vigilance is advisable.

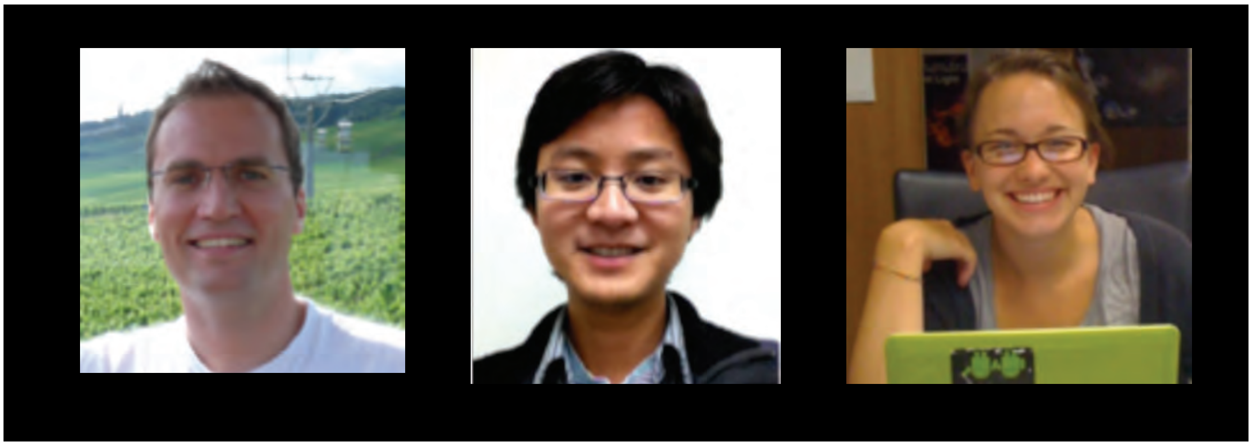
Many brown dwarfs closer than 30 light years have been found, but less than 10% of the brown dwarf candidates seen by WISE have been studied well enough to determine temperatures and distances. So further study of the WISE catalog will probably lead to very cold objects and to objects closer than 5-10 light years.

## Galactic Center Group

### Andrea Ghez

**Andrea Ghez** and her research team began a new program to study star formation at the Galactic center, exploiting the new wide field capabilities of Hubble Space Telescope with the recently installed Wide Field Camera 3. By studying young stars located in the most physically extreme region of our Galaxy, they are testing star formation theories, which suggest that such environments should favor high mass stars and, in extreme cases, should suppress star formation entirely. These wide-field observations provide an important complement to their higher resolution, but smaller field Adaptive Optics studies carried out at Keck Observatory; Figure right shows the first data sets obtained for this program, which offers a stunning view of the center of the Galaxy, revealing populations of stars that have never been detected before. Probing how the properties of the emergent stellar populations within our Galaxy may be affected by the physical environment in which they arise is an important first step to understanding how they might vary as a function of cosmic time and thereby affect our models of galaxy formation and evolution.

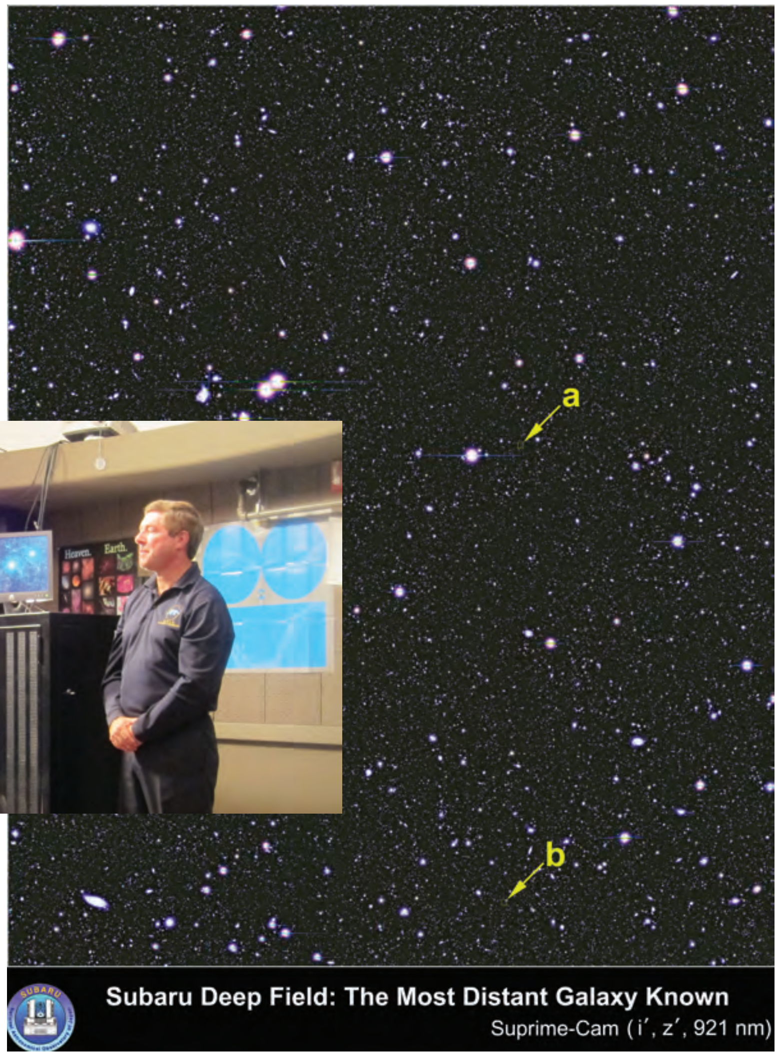
The Ghez group has also had some "good-byes" and "hellos" to do over the last year. **Leo Meyer** (pictured on the left) joined the group as an Assistant Researcher. He brings to the group expertise in General Relativistic modeling of the physical processes close to the supermassive Black Hole in the center of the Milky Way. He earned his PhD from the University of Cologne, Germany, in 2008, took a postdoctoral fellowship to UCLA afterwards, and spent the past two years working in industry before coming back to academia. **Tuan Do** (middle) defended his PhD in August 2010; for his dissertation he carried out one of the first high angular resolution spectroscopic studies of the stellar population at center of the Milky Way galaxy and he found that there is a dearth of old stars compared to what theoretical model predict, which has important implication models of galaxy evolution. He is now a post-doc at UC Irvine working on the science cases and data simulations for the next generation integral field spectrograph for the Thirty Meter Telescope. We also had the pleasure of working with **Anna Boehle** (right) from Smith College through the department's NSF sponsored Research Experiences for Undergraduates.



# Extragalactic Astronomy

## Matt Malkan

**Chun Ly** received his PhD working with **Matt Malkan**, on one of the largest "Deep Fields" ever observed. They combined extremely sensitive observations of an area somewhat larger than the Full Moon. (covering 25 different infrared, optical and ultraviolet wavelengths) from many telescopes around the world, and in space. Dr. Ly's dissertation analyzed the resulting sample of several hundred thousand galaxies in the "Subaru Deep Field". Ly and Malkan used this unprecedented dataset to obtain the most complete census of all types of galaxies, measuring how they have evolved over a huge range of cosmic history--from 11 billion years ago, to the present epoch. Ly was supported during this research on a NASA Graduate Research Fellowship. He won a prestigious Giacconi Fellowship, under which he is continuing research on cosmic evolution at the Space Telescope Science Institute.




Malkan's earlier discovery, with Japanese colleagues, of extremely distant galaxies (seen less than 1 billion years after the Big Bang) in the Subaru Deep Field, was awarded the 2010 Best Publication Award by the Astronomical Society of Japan. Malkan also won a number of international awards to support research and travel to foreign institutions, including the Mexican Academy of Sciences' "Distinguished Visiting Professor" (Puebla and Ensenada), Japanese Society for the Promotion of Science (Tokyo) and the UK National Research Council (Cambridge).

On the lighter side, Malkan continues working to explain astronomy to the wider public. Once in awhile, this proselytizing includes taking a risk in a venue that leans more to the 'popular', rather than the 'scientific' side. In particular, he was interviewed for the TV series "Decoded", where he argued that—contrary to popular rumors—the Earth is under very little threat from extraterrestrial impacts in the year 2012.

# Galactic and Extragalactic Astronomy

## R. Michael Rich

**R. Michael Rich** led the Bulge Radial Velocity Assay team in making a significant discovery about the central bulge of the Milky Way: it is almost completely dominated by a stellar population whose shape is elongated, a so-called bar. Juntai Shen (Shanghai Obs.) fit the BRAVA's survey of stellar radial velocities to his N-body model of the Galaxy. Since the original studies of Walter Baade in the 1950s, astronomers had thought that the Milky Way's bulge was part of its old, metal poor halo, more akin to the globular clusters. The new work showed conclusively that such a population, if even present, can only account for 4% of the mass of the bar. This result is significant, because it contradicts the widely accepted LCDM theory of galaxy formation, which requires that central bulges form from the infall of smaller galaxies. Instead, our Milky Way's bulge appears to have formed from a primordial massive disk of stars. The result was based on **Christian Howard's** Ph.D. thesis. The bulge hosts an array of globular clusters, but none more strange than Terzan 5. To the eye, Terzan 5 looks like a normal star cluster. In reality though, it is unique: it is actually two clusters. One stellar group has 3 times the iron of the Sun, and is 6 billion years old. The other group-part of the same cluster- has stars about half as metal rich as the Sun, but enhanced in elements like oxygen, silicon and magnesium, and 11 billion years old. One theory proposes that this cluster was once the nucleus of a dwarf galaxy some 10-100 times as large as the globular cluster we see today; hence there was enough gravity to retain the gas from which the two groups of stars formed. The central bulge of the galaxy might even have been built from the disintegrations of stellar systems like these. The research used the NIRSPEC spectrograph at Keck, and was collaborative with Livia Origlia of Bologna Observatory. The bulge stellar population revealed additional secrets to NSF post-doctoral fellow **Christian Johnson,** who worked with Rich exploring the composition of stars in the Galactic bulge. Based on a general enhancement of elements made in massive star supernovae, Rich, and Johnson showed that over a volume some 3000 light years in diameter, the bulge formed rapidly, likely in under 1 billion years.

Postdoctoral scientist **Yeong Shang Loh** worked with Rich on data from the Galaxy Evolution Explorer. Using GALEX, they shed light on a very interesting problem. We know that massive red galaxies like ellipticals (filled with old stars) live in dense clusters. Star forming galaxies appearing blue (due to their young stars) are found in places of very low densities. There are in-between galaxies that are compact and dominated by red stars, yet have some star formation. Loh and Rich showed that showed that these galaxies appear to be found in small groups appear to be well on their way to joining dense clusters of galaxies. Former UCLA postdoc **Samir Salim** and Rich discovered that many of these old, compact galaxies have something very massive going on in the ultraviolet: they are forming stars, possibly from gas accreted from the intergalactic medium. The study has provided an important contribution in our understanding of why, over the last 10 billion years, the total mass of stars in these red elliptical galaxies has more than doubled. As these galaxies gather into groups, they interact, igniting star formation- but also consuming hydrogen gas. These processes give insight into why cosmic star formation has experienced an overall decrease in the last 10 billion years.

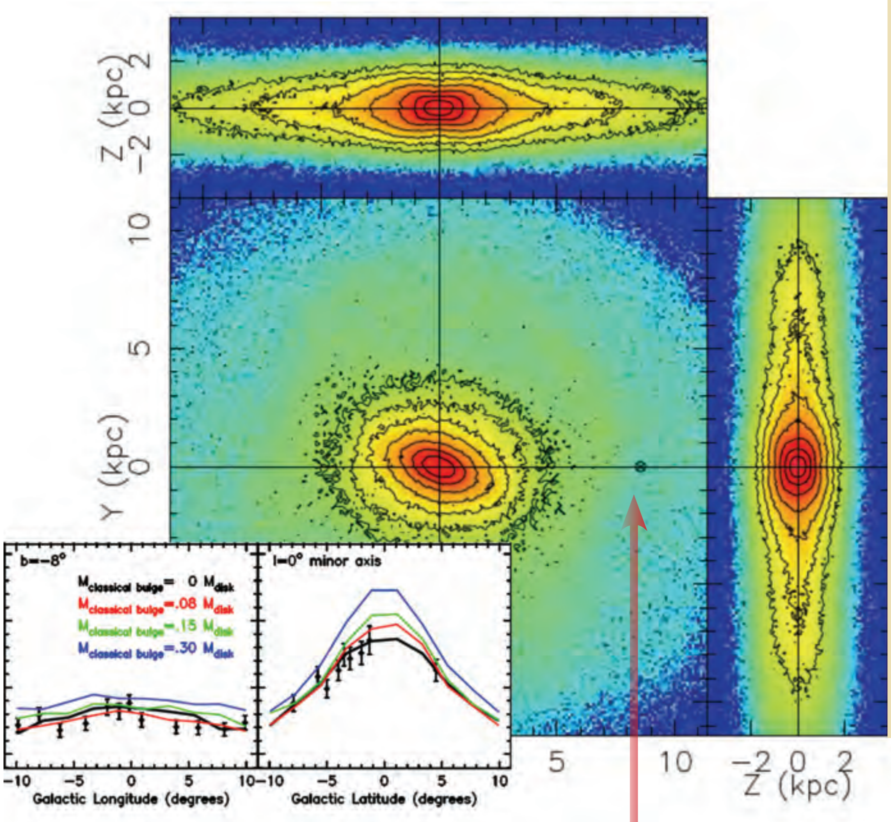



Figure 1: N-body model of the Milky Way Galaxy by Juntai Shen and Michael Rich. Notice that the central concentration of stars is elongated- the so-called bar. In the lower left, the radial velocities of red giants in the Galactic bulge, measured by Christian Howard for his Ph.D. thesis, are plotted against Galactic latitude and longitude, in comparison with a range of Shen's models. The red arrow points at a small dot that indicates the Sun's position in the Milky Way, in this model of our Galaxy. The black line is a model dominated by the bar, and is the best fit to the data. Other lines, which include a larger spheroid component, fit the data poorly. The work suggested that the bulge formed from an existing massive disk strongly supports the theory that the bulge formed from mergers of smaller systems.

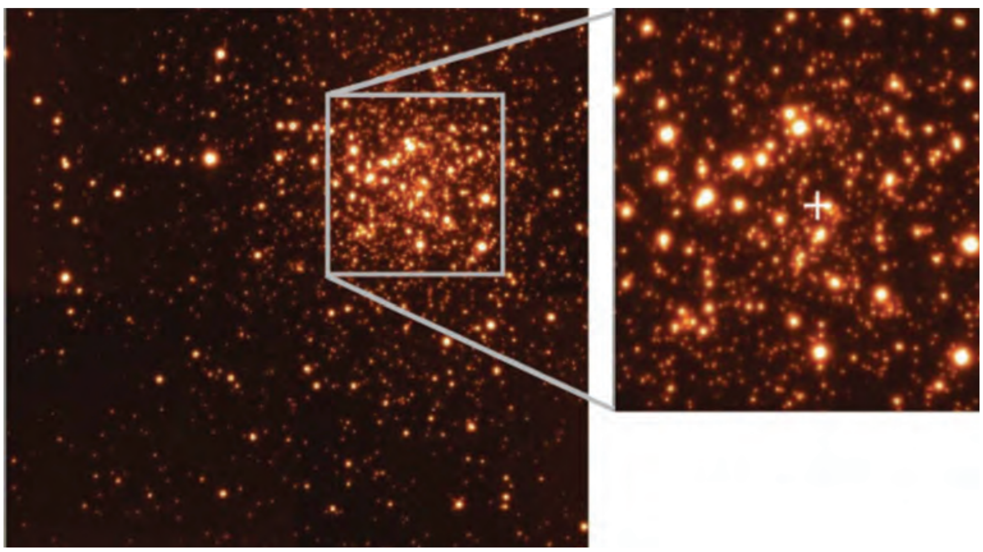


Figure 2: The mysterious globular cluster Terzan 5 was imaged by the European Southern Observatories' Very Large Telescope; the resolution is roughly 5 times as good as is normally seen from the ground. Using Keck observatory and the laser guide star adaptive optics system, Michael Rich and Francesco Ferraro are attempting to measure brightnesses of stars 1000 times as faint as these in the picture, and hope to find two stellar populations of differing ages. Terzan 5 is unique in our Galaxy, it is the only globular cluster known to contain two stellar populations having dramatically different iron and light element abundance. The cluster may be a fossil remnant of more massive dwarf galaxies that dissolved to build the Galactic bulge.

# High-Redshift Galaxies

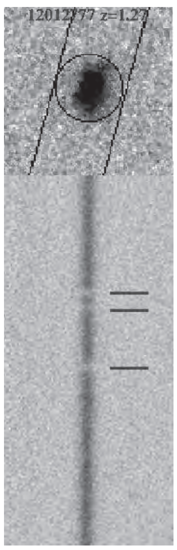
## Alice Shapley

The Shapley Group on the 3rd-floor patio of PAB: (left to right) Kristin Kulas, Katherine Kornei, Alice Shapley, Kevin Hainline, Robin Mostardi, Daniel Nestor.

**Alice Shapley and the High-Redshift Galaxy Group** is pursuing the fundamental question: "How do galaxies get and lose their gas?" Galaxies obtain gas in the course of cosmological accretion, and lose it through the process of large-scale outflows. The regulation of gas in galaxies directly impacts the rate at which stars form and black holes are fueled. Therefore, an understanding of the cycle of gas into and out of galaxies will elucidate the evolution of the overall activity in galaxies as a function of cosmic time. Using the Low-Resolution Imaging Spectrometer at the Keck Observatory, we have obtained spectra probing circumgalactic gas in a large sample of galaxies in the early universe. We focus our investigations on galaxies at cosmological distances of 8 to 11 billion light years, probing a time when the universe was only a few billion years old, and galaxies were still very much in a formation phase. While pinpointing the trends that govern large scale outflows of cool interstellar gas, we have also found some intriguing evidence of gas inflow. This inflow, as indicated by redshifted absorption from interstellar gas relative to the stars, and in the distinctive profiles of emission from hydrogen gas, has previously been notoriously difficult (seemingly impossible!) to detect. Our detections of infalling gas will provide critical observational constraints on models of the growth and overall activity of galaxies. We are also continuing our investigations of the contribution of galaxies to the Universal reionization process, the growth of structure in distant galaxies, and the coevolution of stars and black holes in the early universe.

Finally, we are thrilled to highlight the kick-off of the Southern California Center for Galaxy Evolution (CGE; *http://www.cge.uci.edu*), a multi-campus research program among UCLA, UCSB, UCSD, UCR, and UCI faculty, postdocs and students, sponsored by the UC Office of Research.

The CGE was formed to foster collaboration, support talented postdoctoral fellows through a prize fellowship program, and host conferences, all in the area of galaxy formation and evolution. It boasts roughly 25 participating faculty members, and 5 CGE prize fellows, including Dr. Molly Peeples at UCLA. Alice Shapley is a member of the CGE Governance board.




At the top is a Hubble Space Telescope (HST) image of star-forming galaxy 12012777, which is almost 9 billion light years away (i.e., at a redshift of z=1.27). Below the image is our Keck spectrum of the object, with wavelengths of light spread out from blue to red (i.e. short to long) as we scan from bottom to top. We have marked with blue horizontal lines the locations of absorption lines tracing circumgalactic gas, which is flowing out from this galaxy at hundreds of kilometers per second. Large-scale outflows of gas play a critical role in regulating the formation and evolution of galaxies.

# Astroparticle Physics

## Rene Ong and Vladimir Vassiliev

The astroparticle physics group led by **Rene Ong** and Vladimir Vassiliev is carrying out research in several exciting areas. The main project is the Very Energetic Radiation Imaging Telescope Array System (VERITAS) - an array of four 12m diameter telescopes that detects very high energy (VHE) gamma rays via the atmospheric Cherenkov technique.Since completion of construction in 2007, VERITAS has been remarkably successful, detecting more than 40 astrophysical sources of VHE gamma rays.These objects include supernova remnants, X-ray binary systems, pulsars and pulsar wind nebulae, active galactic nuclei and starburst galaxies.

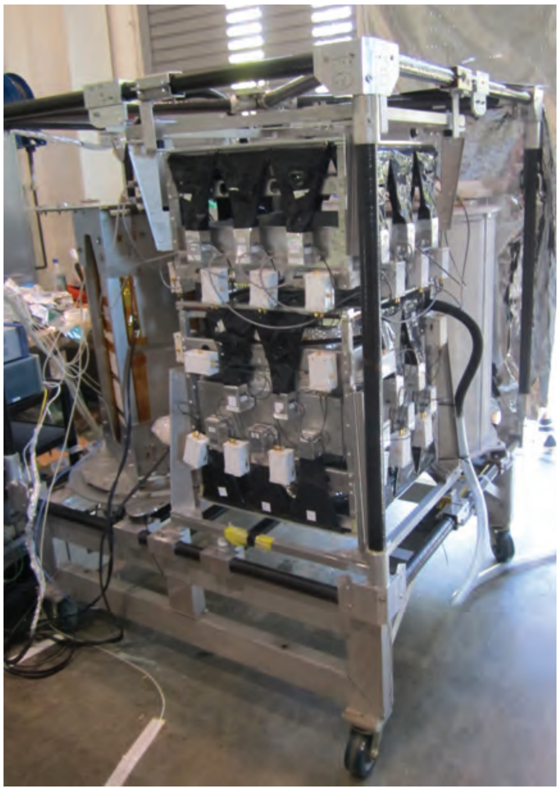
The UCLA team on VERITAS is involved in a broad range of science topics, including galactic astrophysics involving supernova remnants, pulsars and unidentified sources, extragalactic astrophysics involving active galactic nuclei (AGN), and astroparticle physics involving dark matter and intergalactic radiation fields.Among other things,staff researcher **Pratik Majumdar** and new graduate student Alexis Popkow are working on a study of new objects found in the VERITAS galactic plane sky survey and a similar survey done at lower energies by the Fermi satellite telescope. Graduate student **Tim Arlen** is working on the first determination of the intergalactic magnetic field via spectral and temporal signatures of the emission from distant AGN. Research continues in the search for evidence of dark matter through its particle interactions to produce VHE gamma rays detectable by VERITAS.

An important result reported this year was the discovery by VERITAS of VHE gamma rays from the Crab Pulsar.The Crab, the remnant of a supernova explosion observed in 1054, is a famous astronomical object that is much studied at all wavelengths.The pulsar, the spinning neutron star at the center of the nebula, has been detected at gamma ray energies before, but never in the very high energy band above 100 GeV. The VERITAS discovery indicates that there must be a new and unexpected emission component from the Crab and shows that this component arises from a different region in the outer magnetosphere. The Crab Pulsar result from VERITAS is reported in the October 7, 2011 issue of the journal Science.

The scientific success of VERITAS motivates a major follow-up instrument with even greater capability. Ong and Vassiliev are working on the next major ground-based gamma-ray observatory called the Cherenkov Telescope Array (CTA).This observatory is planned to have 50-75 atmospheric Cherenkov telescopes covering an area greater than1 square kilometer. The UCLA effort is focused on the development of a novel two-mirror telescope system that would achieve superior angular resolution and wider field of view relative to existing designs. The group is also involved in studies of possible sites for CTA and is taking the lead on proposing a U.S. site in northern Arizona.

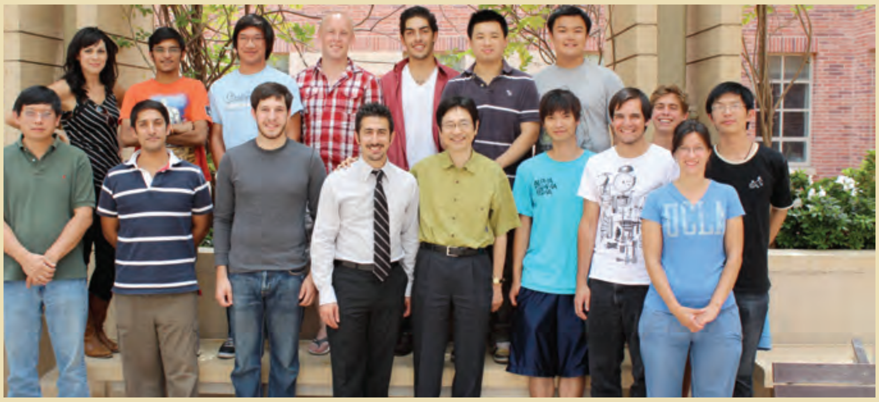
Ong is leading a team at UCLA that is involved with the development of a balloon-borne experiment called GAPS (General AntiParticle Spectrometer) that will search for dark matter. GAPS aims to make the first detection of anti-deuterons in the cosmic rays that could come from the annihilation of dark matter particles.In the GAPS instrument,an anti-deuteron would be detected through its interaction in lithium-drifted silicon detectors (Si(Li)). Layers of the primary Si(Li) detectorswill be surrounded by a large scintillation detector array that would serve as a time-of-flight system and as an anti-coincidence veto. With an Antarctic flight of 25 days,the full GAPS instrument would be sensitive to a large fraction of dark matter parameter space.

Supported by NASA, GAPS is currently in the development phase. A prototype instrument (see photo) has been assembled for a launch in early 2012. This prototype will text the basic detector components in a realistic flight environment. The UCLA group, including Ong and researchers **Jeffrey Zweerink** and **Isaac Mognet** built the time-of-flight and trigger systems for the prototype.



# Dark Matter Group

## Katsushi Arisaka, David Cline, Hanguo Wang



The field of cosmology is entering a very exciting period in which precision measurements support a self-consistent model of the Universe with contributions of 23% from a 'dark matter' component. The detection of this dark matter is recognized as one of the greatest contemporary challenges in science. Building on expertise with previous world-leading instruments developed by **David Cline** and **Hanguo Wang**, coupled with advanced photodetector development by **Katsushi Arisaka** and **Hanguo Wang**, UCLA conduct research to be amongst the first to provide a definitive signal. Uniquely, the UCLA group work with both liquid xenon and liquid argon detectors to contribute to both XENON100 and DarkSide experiments, both of which achieved major goals this past year.

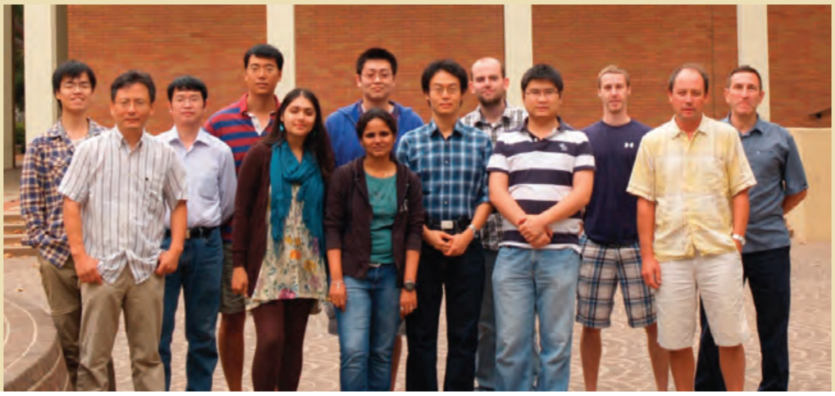
XENON100, operating a liquid xenon detector under the Gran Sasso mountains in Italy, published results from 100 days of blind data taking to set the world's most sensitive limit to date. XENON100 continues to accrue exposure and results from an extended dataset will be published this year. The result will either provide a first detection, or further confine the parameter space for dark matter particles.

The complimentary liquid argon program DarkSide has also made significant progress, installing its first instrument, DarkSide10, at Gran Sasso. Already taking fully shielded calibration data, it is a test bed for the DarkSide50 instrument that will be commissioned in 2012 and search for dark matter.

The dark matter group has produced 3 PhD graduates this past year (**Chi Wai Lam, Ethan Brown,** and **Artin Teyourian**) with a further 3 active in the group presently (**Alex Cahill, Kevin Lung**, and **Yixiong Meng**). he research team has been supplemented by 3 new post-doctoral researchers making a total of 5 (**Paolo Beltrame, Chamkaur Ghag, Emilija Pantic, Paul Scovell** and ).

# Research Highlights physics

## Nuclear Physics Group



The UCLA Relativistic Heavy Ion and Intermediate Energy Physics Group (left to right):

Yuxi Pan,
Huan Zhong Huang,
Xiaohua Liu,
Gang Wang,
Midhat Farooq,
Neha Shah,
Brian Zhu,
Feng Zhao,
Jay Dunkelberger,
Wenqin Xu,
Keith Landry,
Oleg Tsai and
Stephen Trentalange

**The UCLA Relativistic Heavy Ion and Intermediate Energy Physics Group** is a leading university group in the STAR collaboration at the Relativistic Heavy Ion Collider (RHIC), a national nuclear physics facility at Brookhaven National Laboratory on Long Island, New York. We had a very successful run at RHIC in FY2011. The STAR collaboration has collected a substantial amount of data for p+p collisions with transversely polarized beams at 500 GeV center-of-mass energy. In addition, we have completed our first phase of data-taking for the RHIC beam energy scan program to search for a possible critical point at a finite baryon chemical potential in the QCD (Quantum ChromoDynamics) phase diagram. The UCLA group has been responsible for the operation and maintenance of the STAR Barrel ElectroMagnetic Calorimeter (BEMC) and the Forward Meson Spectrometer (FMS) systems. These detectors are critical for our RHIC physics program and have operated very smoothly during the 2011 run.

We have also made several major advances in our scientific program. The STAR collaboration discovered the anti-alpha particle (made of two anti-protons and two anti-neutrons) in Au+Au collisions, which is the heaviest anti-matter that has ever been observed. The formation of anti-alpha in nucleus-nucleus collisions results from unique collision dynamics that a large number of anti-protons and anti-neutrons are produced per collision and there is a finite probability that these anti-nucleons in proximity of phase space can coalesce to form anti-alpha. The STAR Time-Projection Chamber allows us to record and reconstruct thousands of charged particles produced from Au+Au collisions (Figure 1). We have to sift through more than half trillion reconstructed particles from almost half billion Au+Au collision events to find 18 anti-alpha particles. Because of the small coalescence probability the production rate for anti-nuclei suffers a penalty factor of more than 10^3 with the addition of each anti-nucleon (Figure 2). It is unlikely that there will be anti-matter beyond anti-alpha to be discovered in a laboratory in the near future with the existing accelerator technology.

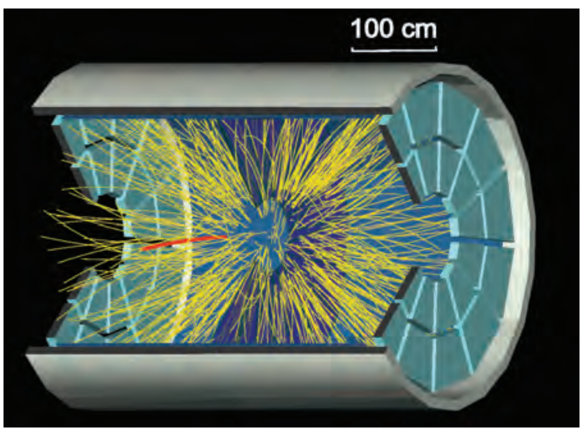



Figure 1: charged particles are reconstructed from the STAR Time-Projection Chamber (TPC), and are identified with the barrel Time-of-Flight detector and the ionization measurement in the TPC.

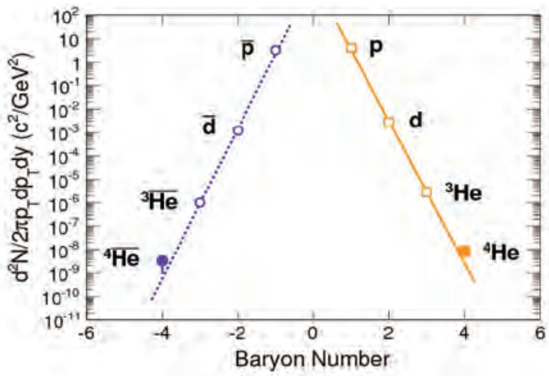



Figure 2: Differential invariant yields as a function of baryon number B, evaluated at pT/|B| = 0.875 GeV/c, in central 200 GeV Au+Au collisions. Details can be found in Nature 473, 353 (2011).

We have also accomplished a number of important measurements recently at RHIC. We experimentally separated the Bottom and Charm quark semi-leptonic decay contributions to electrons and positrons in p+p collisions. When combined with the measurement of nuclear modification factors for these electrons/positrons from Au+Au collisions, our result indicated that even Bottom quarks must suffer considerable energy loss while traversing the high temperature and high energy density Quark-Gluon Plasma created in nucleus-nucleus collisions at RHIC *[Phys. Rev. Lett. 105, 202301 (2010)]*. We have measured the total Bottom quark production cross section from p+p collisions at 200 GeV beam energy [*Phys. Rev. D83, 52006 (2011)*]. We have observed for the first time the parity-violating longitudinal single spin asymmetry of W boson production from polarized p+p collisions at 500 GeV, which is sensitive to anti-quark polarization from sea quarks in the proton [*Phys. Rev. Lett. 106, 62002 (2011)*]. The UCLA group continues our investigations of beam energy dependence of the reaction-plane dependent charge separation phenomenon and searches for possible local parity violation due to formation of QCD domains and/or meta-stable vacuums in nucleus-nucleus collisions.

We have been carrying out a detector R&D project to develop a calorimeter technology using tungsten powder and scintillating fibers. Figure 3 shows the scintillating fiber arrangements in molds before filling with tungsten powder and a prototype 4x4 matrix of electro-magnetic calorimeter modules. The project is funded by a joint generic R&D program by Brookhaven National Laboratory, Thomas Jefferson National Laboratory and the Nuclear Physics Office of DOE Office of Science. We have scheduled a beam test experiment for the prototype detectors at Fermi National Laboratory in January 2012.

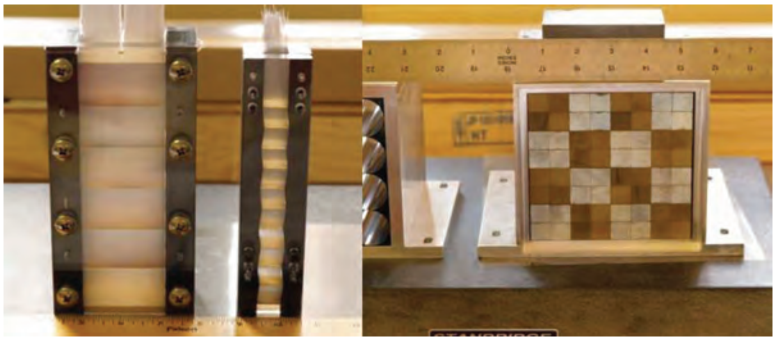


Figure 3: Scintillating fibers in molds before the filling of tungsten powders (left); and the front face of a 4x4 prototype matrix of electro-magnetic calorimeter modules.

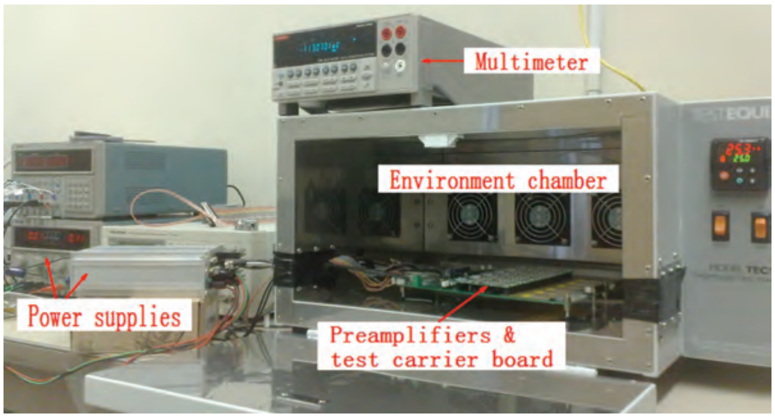



Figure 4: Testing setup for CUORE front-end electronics and its temperature calibration.

The UCLA group is a member of the CUORE $0\nu\beta\beta$ (neutrinoless double beta ) decay experiment currently under construction at the Gran Sasso national laboratory (LNGS) in Italy. We have set up an environmental chamber at UCLA for testing CUORE front-end electronics and performing temperature calibrations (Figure 4). The CUORE detector will consist of 39 towers of crystals in a dilution refrigerator operating at 10 mK temperature. A single tower detector, CUORE-0, will be assembled at the end of this year and will run as an experiment for $0\nu\beta\beta$ decay searches until the CUORE experiment comes online in 2014.

## Nuclear and Particle Physics at Intermediate Energies:

### Bernard Nefkens

The main objective of the Research and Teaching Group "Nuclear and Particle Physics at Intermediate Energies" is testing the validity of the symmetries that control the new features found in subatomic physics. Much work is done on determining the structure of the chief building block of our universe, the proton. The group is led by **Bernard (Ben) Nefkens.** Postdoctoral researchers include **Aleksandr (Sasha) Starostin** and **Serguei Prakhov.** In 2009 two new postdoctoral researchers, **Milorad Korolija** and **Alexander Lapik,** started their collaboration with the group working part-time on the Crystal Ball project at Mainz, Switzerland where the group is spearheading a collaboration of some 12 universities in research on multi-meson photoproduction. Subject of John Goetz doctoral thesis is a search for doubly strange nucleons using the improved CLAS detector at Jefferson Laboratory. John obtained the experimental data for his thesis in 2008 completing the preliminary analysis of the data in early 2010. Now he is finalizing the results which include the production of the ground and the excited cascade states, search for the exotic five-quark cascade states, first attempt to look for the omega baryon photoproduction, and more. **Michael Skuhersky** joined the group in 2010 as an undergraduate Research Assistant. Michael's primary responsibility is to maintain the group's Linux computer cluster, which is heavily used for data analysis as well as Monte Carlo simulation.

The group pursues two experimental programs. One is centered around a special detector, the Crystal Ball multi-photon spectrometer that has an acceptance of almost 4pi steradian. It has been installed in the 1.5 GeV beam of tagged photons at the University of Mainz. This enables measurements of the neutral rare and forbidden eta and eta_prime decays. This tests C, CP, time reversal isospin invariance, and flavor and chiral symmetry as well. Study also includes the photo production of selected neutral mesons with polarized and unpolarized beam and targets to probe the structure of the proton. The second program uses the large CLAS (CEBAF Large Acceptance Spectrometer) detector, which measures charged particles. This device is located in the 5.75 GeV tagged photon beam of Jefferson Laboratory. It is used to investigate cascade hyperons, which are rare, doubly strange baryon specimens. The cascade particles are particularly well suited to study the quark structure of the proton, probing the quark-quark correlations inside the proton.

# Condensed Matter Theory Physics:

## Elihu Abrahams

**Elihu Abrahams'** research is on the application of quantum many-body theory to understand the physical properties of strongly-correlated materials. These are compounds whose behavior is primarily determined by strong interparticle interactions that dominate the various contributions to the energy of the system. His recent research is on the new iron pnictide and oxychalcogenide superconductors and on the heavy-fermion metals. In 2010-2011, the following results were obtained and published:

In a "Topical Review" for Journal of Physics: Condensed Matter, Abrahams *[with coauthor Qimiao Si (Rice) in J. Phys.: Condens. Matter 23, 223201 (2011)]* reviewed the theory and the experimental evidence for a new type of quantum criticality. Here, a magnetic quantum critical point arises out of competition between electron localization and itinerancy. This competition is a central feature in much of the physics of strongly-correlated materials. The theory, by Abrahams and coworkers that led to this discussion is based on treating the pnictides and oxychalcogenides as being close to a correlation-induced metal insulator transition, thus from a strong-coupling perspective.

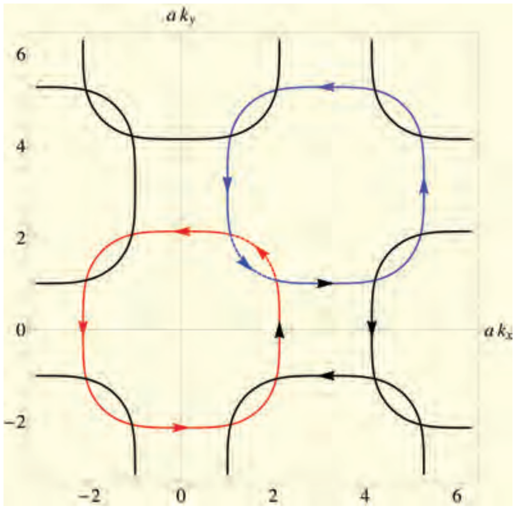
Quantum criticality found in many rare-earth and actinide based "heavy-fermion" metals is at the forefront of condensed matter research. There are competing theories for the behavior in the neighborhood of the quantum critical points. Abrahams has collaborated with Peter Wölfle (Karlsruhe) in developing a new theory of how quantum critical fluctuations in these materials affect the electronic properties. It is an extension of the traditional Landau Fermi-liquid picture that goes beyond the usual theory of weakly-coupled critical fluctuations. This "critical quasiparticle theory" *[Phys. Rev. B 84, 041110 (2011)]* is used to calculate a number of the observed properties of the prototypical heavy-fermion metal, ytterbium-rhodium-silicon. The agreement with experiment is remarkable.

## Alex Levine

In the past year Alex Levine's theoretical research in soft condensed matter and biological physics has explored the mechanics and dynamics of living cells. He and his colleagues studied how one can use the observed fluctuations of cell membranes to determine their mechanics at the submicron scale without perturbing them. This work is based on the principle that spontaneous fluctuations in thermal equilibrium are directly related to linear response of the system to external perturbations. Thus, one can observe the thermally excited deformations of soft microscopic structures and infer their mechanics. This class of noncontact measurements, applicable to the world's softest and most fragile materials, is called microrheology. To use this technique on cells, researchers first have to understand how the cell membrane undulations depend on the underlying mechanics and complex geometry of the cell. To that end, Levine and coworkers explored the spectrum of thermal undulations of red blood cell membranes, which are effectively two-dimensional fluids coupled to a triangular network of protein springs through an array of transmembrane proteins. By exploring the effect of the cell's geometry on the thermal undulations of this complex fluid (lipid bilayer) and elastic (spectrin) network, Levine and coworkers were able to predict the observed fluctuations of healthy human red blood cells, which were in agreement with experiments by the Popescu group in Urbana-Champaign. Turning to diseased and mechanically stressed red blood cells, the Levine and Popescu collaboration were able to trace the mechanical changes in the red blood cell membranes due to disease and to study the nonlinear stiffening of the membranes under imposed stress. The work was reported in *Proceedings of the National Academy of Sciences 107, 6731 (2010) and Physical Review E 83, 051925 (2011).*

## Sudip Chakravarty

In the past year **Sudip Chakravarty** has conducted research in the areas of high temperature superconductivity, topological insulators and quantum criticality. He, along with his student **Jonghyoun Eun**, has provided convincing explanation of the striking quantum oscillations and magnetic breakdown in electron-doped superconductors, published in Physical Review B. An image of the breakdown effects was chosen from this paper to be displayed on the front page of the journal web site (*http://prb.aps.org*). This feature is named "Kaleidoscope" (see right). Along with his postdoc **David Garcia-Aldea** he has provided the reason why quantum oscillations in hole doped high temperature superconductors reflect Fermi surface reconstruction in the singlet channel of a density wave. With his former student **Pallab Goswami,** now a Dirac fellow at the National High Field Magnet Lab, he has analyzed, for the first time, quantum criticality between topological and band insulators in thredimensions. The paper is in press in Physical Review Letters. Experiments similar to that



Breakdown junctions and electron trajectories in the electron-doped high-temperature superconductor.

performed by Zahid Hasan and his coworkers at Princeton are likely to shed light on this important problem *(Xu et al. Science, 332, 560 (2011)*), although it would require more fine-grained data through the topological phase transition.

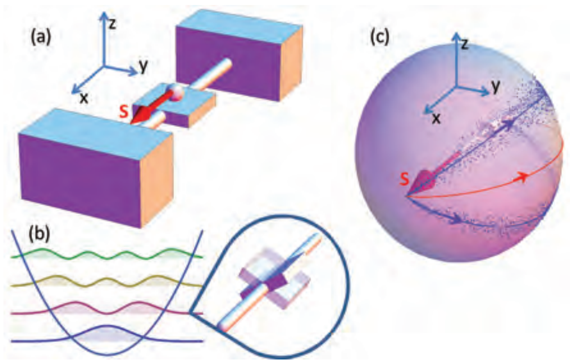
As reported by Dr. Richard Palmer (senior publisher) Dr. Chakravarty's article, "Quantum oscillations and key theoretical issues in high temperature superconductors from theperspective of density waves", in *Reports on Progress in Physics, 74, 022501 (2011)*, has been downloaded 250 times as of March 30, 2011. As stated by Dr. Palmer, across all IOP journals 10% of articles were accessed over 250 times this quarter.

Sudip Chakravarty's research group consists of five graduate students and two postdoctoral associates, one of whom is returning to Spain in November, 2011, with a teaching job. **Dr. Ispita Mandal** has joined his group. She got her Ph. D. in string theory from the well-known Harish Chandra Research Institute in India. In addition, during the past year Sudip Chakravarty has mentored (as a research supervisor) three undergraduates. **Rachel Cane** has joined the graduate school at U. Penn and **Jena Meinecke** has joined Oxford. **Yuezhen (Murphy) Niu** worked with him as an exchange student who has now returned to China to finish her senior year. To her credit, she has collaborated on a cutting edge paper on Majorana fermions that is posted on the arXiv and will be soon submitted for publication. Sudip Chakravarty also collaborates with S. Raghu, a faculty member at Stanford, and Suk Bum Chung, a postdoc at Stanford.

## Yaroslav Tserkovnyak

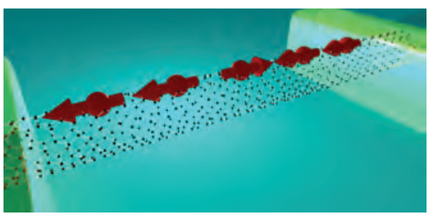
Macroscopic quantum phenomena, of which Josephson junctions and nanomechanical cantilevers are notable examples, have been at the forefront of condensed matter research. Nano-cantilevers are now in the limelight, owing to the recent experimental breakthroughs in reaching the quantum limit.

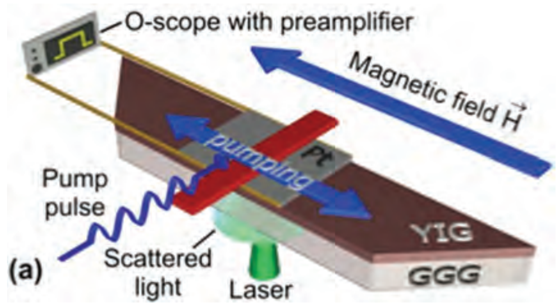
We study how small magnetic nanoparticles couple to such cantilevers, due to magnetic anisotropies that lock spin and mechanical angular momenta into coherent dynamics. We highlight the role of the nanomechanical interference in determining the macrospin tunneling strength and the magneto-mechanical entangled state dubbed magnetopolaron.



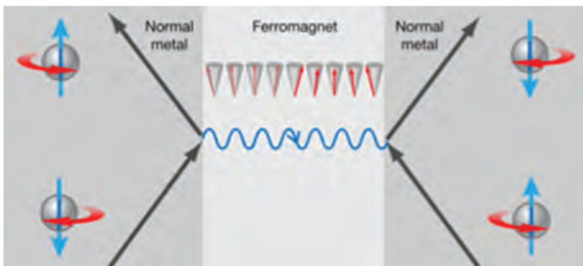
Schematic of our proposeed device
Kovalev, Hayden, Bauer and Tserkovnyak, Phys. Rev. Lett. 106. 147203 (2011)

Our work is aimed at utilizing magnetism for controlling and reading out quantum nanomechanical devices.


A futuristic scaled-up version of a device
Kontos, Physics 4.28 (2011) Viewpoint
"Spintronics meets nanoelectronics"



Experimental realization of our spin pumping by a magnetic Insulator (YIG)
Sandweg et al, Phys. Rev. Lett. 106, 216601 (2011)



Generation and detection of magnons by spin-transfer torque and spin pumping, respectively
Bauer and Tserkovnyak. Physics 4. 40 (2011) Viewpoint
"Spinmagnon transmutation"

From the applications point of view, spintronic and, more recently, spin-caloritronic research is gearing rapidly towards technology based on pure spin transport, particularly in magnetic insulators, where ordinary electron spins are replaced with collective magnon excitations. This shifts spintronics from dissipative Ohmic media to insulators with very low dissipation.

The spin pumping and (its reciprocal) spin-transfer torque, which are a focus of our research, provide the essential physical ingredients to achieve this goal, as well as interface the magnonic and conventional electronic circuits.

The conversion of magnons into electron spin flips via spin pumping may ultimately allow for low-power spin-based data transmission schemes.

# Condensed Matter Molecular Biophysics

## Dolores Bozovic

The **Bozovic laboratory** studies mechanical sensation by auditory and vestibular systems and in particular, detection performed by inner ear hair cells. These specialized cells underlie the mechano-electrical transduction process in the sensory epithelium of the inner ear, and display sensitivity to displacements in the sub-nanometer regime. We developed the use of magnetic particles to actuate the cells and thus probe their dynamics in a non-invasive fashion.

In previous work, we demonstrated that mechanical offset can serve as a control parameter that can tune the response of a hair cell. As predicted by theory, hair bundle dynamics display a bifurcation, which separates the quiescent regime from one in which limit cycle oscillations arise. We were able to demonstrate the transition through the critical point, with an actuation technique that avoids loading the bundles or contributing to the viscous drag. *(Rowland, D., Roongthumskul, Y., Lee, J. H., Cheon, J. and Bozovic, D. (2011) Magnetic actuation of hair cells. App. Phys. Lett., in press.)*

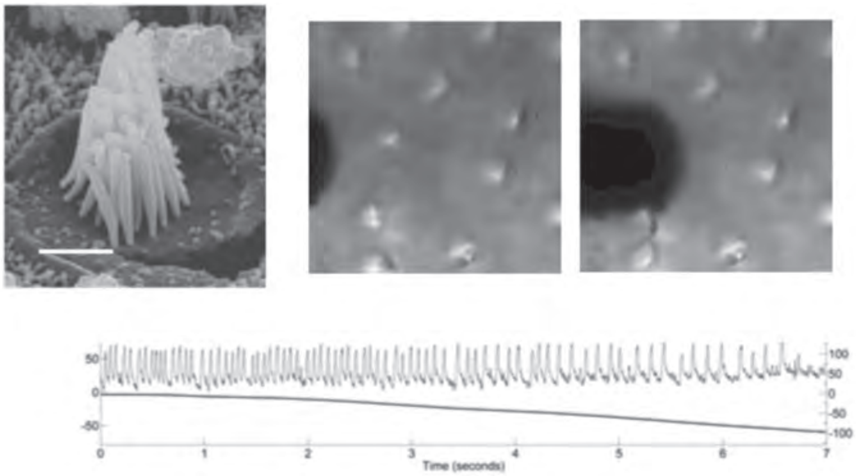



Figure 1: Paramagnetic iron-oxide beads were attached to the tips othe stereocilia, and a magnetic probe was used to impose deflections. This technique allowed us to observe the transition from the oscillatory to the quiescent state.

In a concurrent theoretical study, we proposed a new element to the current models of hair cell mechanics. We postulated the existence of a variable spring as a component of the transduction complex, whose stiffness is dependent on internal calcium concentration. The dynamics of the calcium attachment and detachment is hypothesized to be slow with respect to other cellular processes. Introducing this slow manifold captured a broad range of experimental results, including the bursting-type behavior observed in spontaneously oscillating bundles. *(Roongthumskul, Y., Fredrickson-Hemsing, L. M., Kao, A. and Bozovic, D. (2011) Multiple-timescale dynamics underlying spontaneous oscillations of saccular hair bundles. Biophys. J., 101, 603-610.)*

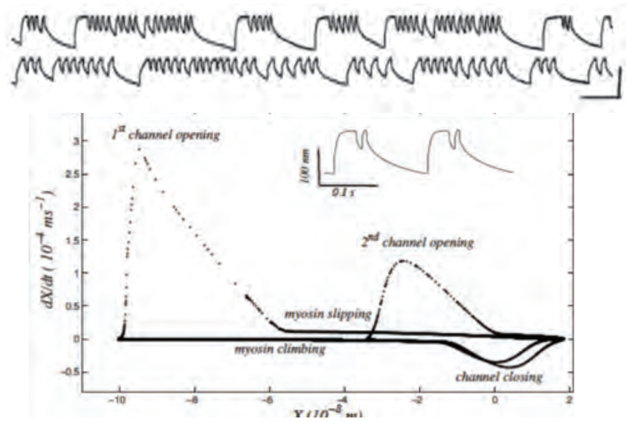



Figure 2: Top: numerical simulations of spontaneous motility in hair bundles, exhibiting multi-mode oscillation. The vertical scale bar indicates 100 nm of displacement, while the horizontal one represents 0.1 second. Bottom: phase portrait of a simulation of a noiseless spontaneous oscillation shown in the inset.

# Molecular Biophysics Lab

## Giovanni Zocchi

Biological macromolecules (enzymes, DNA) couple conformational motion to chemical reactions, binding events, and ultimately function. Research in the **Zocchi Lab** is focused on probing and exploiting this mechano-chemical coupling, using forces and elastic energies to control chemical reactions ("mechano-chemistry"). Thus we are generally interested in molecules under stress.

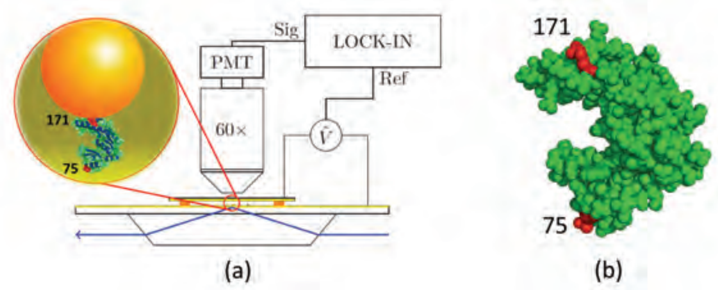



Fig. 1. Gold nanoparticles, tethered to a gold surface by the protein under study (shown in (b)), are driven by an AC electric field while their displacement is synchronously detected by evanescent wave scattering.

**The protein as a viscoelastic solid.**

We have invented a nano-rheology technique which measures the stress – strain relations of the folded state of globular proteins in the frequency range 10 Hz – 10 kHz (Fig. 1). For small deformations (sub-Angstrom), the protein responds elastically and we can measure for example the stiffening of an enzyme when it binds its substrates *[Y. Wang and G. Zocchi, Phys. Rev. Lett. 105, 238104 (2010)]*. Increasing the forcing, we discovered a reversible transition to a state where the protein flows like a viscoelastic material (Fig. 2). This viscoelastic transition is a new materials property of the folded state *[Y. Wang and G. Zocchi, Europhys. Lett. 96, 18003 (2011)]*, which we believe has fundamental significance for the working of enzymes.

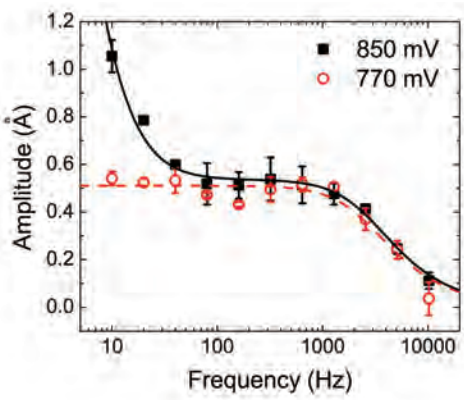



Fig. 2 Elastic (red data) and viscoelastic (black data) response of the enzyme Guanylate Kinase (Fig. 1b) to an oscillatory stress. The black data are obtained for higher amplitude of the stress. The method measures the protein's deformation with sub-Angstrom resolution.

**Nonlinear bending elasticity of DNA.** What happens if you try to bend a molecule? Small molecules break; large molecules get stressed. Through direct measurements of the elastic energy of a series of internally stressed DNA molecules (Fig. 3) we have characterized quantitatively the nonlinear bending elasticity of DNA (Fig. 4). We have obtained an analytic expression for the bending elastic energy of short DNA molecules (plotted in Fig. 5); the nonlinearity is quantitatively described by the critical torque τc at which the DNA molecule develops a kink [*H. Qu and G. Zocchi, Europhys. Lett. 94, 18003 (2011)*]

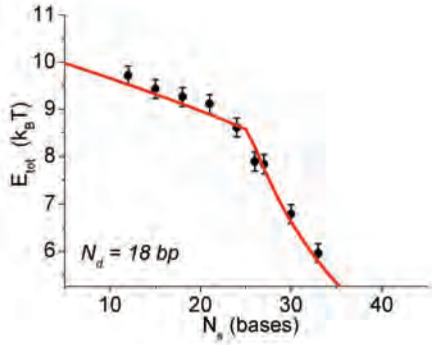



Fig.4 Direct measurements of the elastic energy of a series of molecules as in Fig. 3, for increasing x (here increasing Ns). The red line is calculated from the theory of Fig. 5.

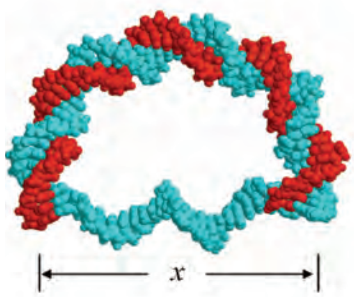



Fig. 3. This DNA molecule is by design internally stressed. The double-stranded part has to bend, while the single-stranded part has to stretch. It is essentially a system of two coupled nonlinear springs, at the molecular scale (x  10 nm).

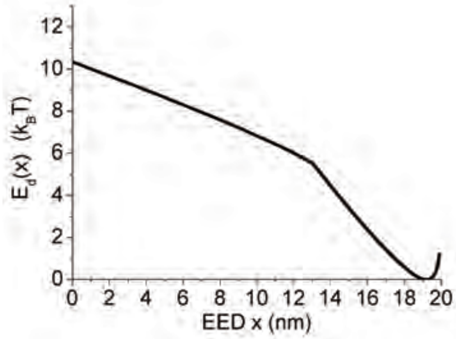



Fig. 5 The bending elastic energy plotted for a DNA 60mer (contour length 20 nm) vs the end-to-end distance (EED) x. The molecule behaves like a nonlinear spring.

# Coherent Imaging Group

## Jianwei (John) Miao

Coherent diffraction imaging (also termed coherent diffraction microscopy or lensless imaging), pioneered by **Miao and collaborators** in 1999, continues under rapid development worldwide. A large number of groups have been working in this field due to the appearance of advanced X-ray sources such as X-ray free electron lasers, table-top coherent X-ray sources and 3rd generation synchrotron radiation. The Miao group regularly travels to the SPring-8 in Japan and the European Synchrotron Radiation Facility (ESRF) in France to perform high-resolution 3D imaging of biological cells and cellular organelles. His group will also conduct a coherent imaging experiment on viruses at the LCLS, SLAC in February 2012. Four papers on this project have been published or accepted in 2011 by the Miao group and collaborators: *i) Chen et al. Phys. Rev. B 84, 024112 (2011); ii) Miao et al., IEEE J. Sel. Top. Quant, in press (invited review); iii) R. Xu et al., J. Synch. Rad. 18, 293 (2011) and iv) Seaberg et al., Opt. Express 19, 22470 (2011).* Furthermore, Miao was recently invited to write review articles on coherent diffraction imaging by two high-profile biophysics journals: Quarterly Review Biophysics and Current Opinion in Structural Biology. Graduate students and postdocs, including **Jose Rodriguez, Chien-Chun Chen, Jeff Huang, Rui Xu, Sara Salha, Phuc Hoang and Even Zou** have been involved in this project.

The other projects in the Miao group are related to equally sloped tomography (EST), a novel tomography method originally developed by Miao and collaborators in 2005. Compared to classical tomography that reconstructs a 3D object from a tilt series of projections with constant angular increments, EST acquires a tilt series with equal slope increments and hence enables to reconstruct a 3D object by using the pseudo-polar fast Fourier transform with iterative algorithms. Recently, they have applied EST to low-dose 3D imaging of a human breast cancer sample. A tilt series of phase-contrast X-ray images was measured from the cancer sample at the ESRF. The reconstruction results indicated that EST with 512 projections produced a 3D image with comparable or better image quality than classical tomography with 2000 projections, suggesting a radiation dose reduction by ~70%. EST was also applied to the 3D structure determination of a 10 nm gold nanoparticle at 2.4 Å resolution by using a scanning transmission electron microscope at the CNSI. Single atoms were observed inside the nanoparticle and several 3D grains were identified at atomic scale resolution. It is anticipate this general method can be used to determine the 3D structure of crystalline, polycrystalline and potentially disordered nanomaterials at atomic scale resolution. Graduate students and postdocs, **Janice Zhao, Mary Scott, Chien-Chun Chen, Chun Zhu, Jeff Huang and Rui Xu,** have been involved in the EST projects. Other collaborators include **Matt Mecklenburg, Chris Regan** of UCLA, Peter Ercius, Ulrich Dahmen of LBNL, Emmanuel Brun and Alberto Bravin of the ESRF.

# Neurophysics Group

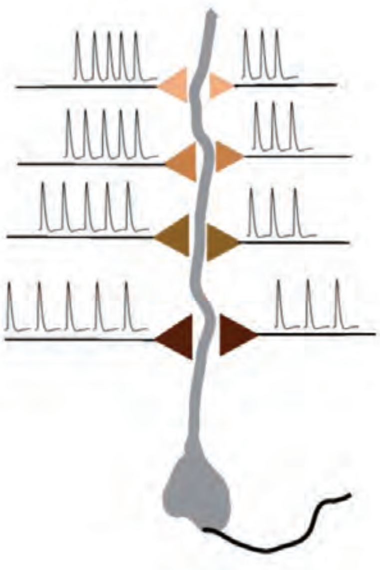
## Mayank Mehta

**The Neurophysics group** has eight graduate students (**Lavanya Acharya, Zahra Aghajan, Daniel Aharoni, Zhiping Chen, David Ho, Ashley Kees, Jason Moore, Bernard Willers)**, four postdocs (**Jesse Cushman, Maryam Ghorbani, James McFarland, Pascal Revassard)** and four collaborating faculty (**Katsushi Arisaka, Robijn Bruinsma, Alex Levine and Joseph Rudnick**).

The laboratory has generated seven papers in the past year, of which four have been published, and three of these are described below.

Project 1: Even in the absence of all stimuli, the brain is spontaneously active. An understanding of this 'ground' state of the brain is necessary. We measured neural activity of individual neurons and large ensembles, and developed Hidden Markov based analysis methods to show that even when the neural activity looks normally distributed, it consists of two underlying states with distinct activity levels and spectral content, and the brain makes transitions between these two states about once a second.

Project 2: How does the brain perceive space and navigate? We measured the activity of neurons that contain information about our position in space. It was thought that this was sufficient to navigate. We argued that to navigate one also needs information about velocity, and that position and speed information should be carried by independent variables. A position-independent code for velocity was unknown. Using experimental measurements and novel time-frequency domain analysis methods we demonstrated the existence of a novel neural code for speed. It turns out that 30-100Hz neural oscillations encode running velocity.



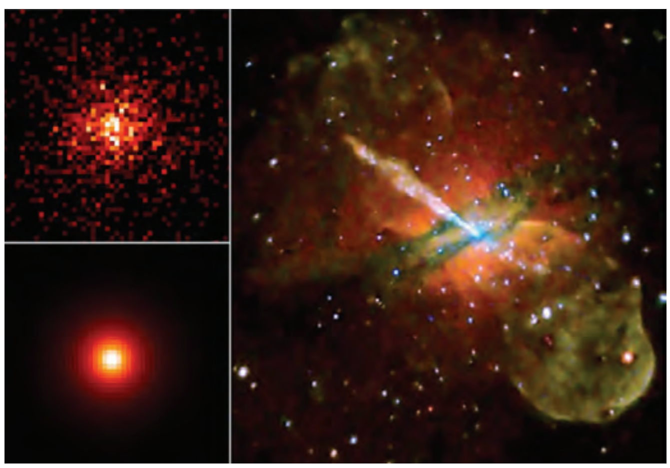
Project 3: How does the brain learn? While information is represented by neural activity levels, information is learned and memorized using the strengths of synapses connecting neurons. A theory of how synaptic strengths change during natural behavior is crucial but missing. We developed such a theory which showed, using analytical and numerical calculations that the synaptic strength behaves as $1/f$ where $f$ is the frequency of neural activity. This is quite surprising and predicts that neural oscillations would profoundly influence learning, and that the neurons act as large antennae with different portions tuned to distinct frequency for optimal learning (figure). These findings received extensive media coverage at *http://www.physics.ucla.edu/~mayank/news.html*

# Theoretical Elementary Particle Physics and Astrophysics

## Alexander Kusenko

**Alexander Kusenko** did theoretical work on dark matter and explored the expected signals at the Large Hadron Collider. In addition, he participated in a dark matter search using XMM-Newton X-ray telescope in space, in collaboration with **Michael Loewenstein,** a NASA astronomer and a UCLA alumnus.

Kusenko also studied the role of cosmic rays in forming the observed spectra of distant blazars together with a UCLA student **Warren Essey,** who graduated in 2011 and accepted a postdoctoral position at UC Berkeley. A related work done with **Shinichiro Ando (**who has just accepted a faculty position at U. of Amsterdam) has produced exciting new insights regarding magnetic fields in deep space between galaxies.
Kusenko co-organized international conferences in Tokyo, Japan, Snowbird, Utah, and Moorea, French Polynesia, at which six UCLA graduate students and alumni were among the speakers. Kusenko's scientific results were highlighted in Science, Nature, Scientific American, and other broadly read publications. Kusenko gave four departmental colloquia and three public lectures, one of which was broadcast on local television in Aspen, CO, and in other locations where Grass Roots TV Channel is available.



The Force? A composite image of 170 supermassive black holes like this one (right) proved fuzzier in reality (upper left) than predicted by computer models (lower left). Credit: Source: NASA; (insets, top and bottom) S. Ando and A. Kusenko, The Astrophysical Journal Letters (October 10, 2010)

## Eric D'Hoker, Michael Gutperle, Per Kraus

**Eric D'Hoker and Per Kraus** are investigating thermodynamic and transport properties of fermions in strongly interacting gauge theories using string theory ideas and techniques. Specifically, the Maldacena gauge/gravity duality maps a strongly coupled gauge theory in 4 space-time dimensions onto an effective Einstein-Maxwell gravity theory in 5 dimensions. The extra dimension essentially plays the role of a varying length scale. Quantum states in gauge theory are mapped to solutions of the gravity theory. If a gravity solution contains a black hole, then the corresponding gauge theory state is thermal. Its temperature coincides with the Hawking temperature of the black hole. A finite charge density (or equivalently a chemical potential) and/or an external magnetic field may be introduced on both gauge and gravity sides, thereby providing an exciting semi-realistic theoretical laboratory for the study of strongly correlated fermions

Using a combination of analytical methods and high-precision numerical analysis to study the existence and behavior of gravity solutions with black holes, D'Hoker and Kraus have shown that 4-dimensional gauge theory undergoes a quantum phase transition as the external magnetic field B approaches a critical value B_c. Near this quantum critical point, the specific heat coefficient diverges as 1/(B-B_c) at zero temperature, signaling the onset of non-Fermi liquid behavior. The corresponding dynamical scaling exponent is found to be 1/3. These results, originally inferred from numerical study, were later derived analytically from the existence and regularity properties of new electrically charged magnetic black hole solutions.

Actually, the story is more complicated and also more interesting. In the effective 5-dimensional gravity description, the gauge theory strong coupling dynamics is characterized by a single free parameter k. In fact, k governs the strength of the chiral anomaly and gives a measure of the number of chiral fermion species in the gauge theory. It is becoming clear that the strong coupling gauge dynamics exhibits a remarkably rich structure as a function of k. For example, the quantum critical point only exists for k > 1/2; all super-symmetric gauge theories must have k^2=4/3; the dynamical critical exponent takes the value of 1/3 only when k > 3/4; but varies continuously when k < 3/4; and so on.

These quantum phase transitions involve non-analytic behavior of the specific heat and magnetization as the magnetic field crosses a non-zero value, but no change in symmetry. They are often referred to as meta-magnetic transitions. One physical application is to certain magnetic solid state materials, where the strongly coupled fermions are electrons. Indeed, above the critical magnetic field, the scaling behavior found from string theory is consistent with the predictions of the Hertz/Millis theory of meta-magnetic quantum phase transitions, such as have been observed experimentally in compounds like Strontium Ruthenates. Another physical application, which remains to be explored, may be to quark-gluon plasmas, in the presence of external magnetic fields. Here, the strongly coupled fermions are quarks.

Over the past year, **Michael Gutperle** and Per Kraus, together with UCLA postdoc **Martin Ammon** and UCLA graduate student **Eric Perlmutter,** have discovered and are studying a quite novel type of black hole. Gravity is well established as being governed by Einstein's General Theory of Relativity over sufficiently large distance scales. However, it is widely believed that General Relativity breaks down at very short distances, and that our usual notions of space-time have to be altered in this regime. Such a breakdown is exhibited in string theory, where the finite string size leads to a completely new, but poorly understood, generalization of ordinary geometry on distances scales of order the size of a string. A major challenge of theory is to apply this new notion of geometry to physical systems under extreme conditions, such as occur in black holes and cosmology. Unfortunately, the technical complexity of string theory has allowed only very limited insight into this problem so far. But recently progress has been achieved by working with a simpler theory, which is believed to provide a good model of string theory in the regime of interest. This theory, known as "higher spin gravity", extends General Relativity by partnering the graviton (the massless particle responsible for the gravitational force) with an additional set of "higher spin" particles. The presence of these extra particles gives rise to qualitatively new effects.

A famous consequence of Einstein's Special Theory of Relativity is that there is no absolute notion of time: given two events, different observers can disagree as to which occurred first. However, all observers agree on the causal relation between two events; for instance whether or not a light signal emanating from event A can or cannot arrive at event B. This notion of ``causal structure" features prominently in Einstein's theory of gravity, but is something that might or might not make sense at very short distances. The discovery of black hole solutions in higher spin gravity has opened a new window through which to study these issues. One of the most dramatic findings has been that the causal structure of the black hole space-time becomes ill-defined at a fundamental level. The question of whether or not event A can causally affect event B becomes ambiguous, because it is not possible to localize events to arbitrary accuracy. In a sense, the presence of the higher spin particles smears out the idealized points associated with a classical notion of space-time.

A fascinating property of these black holes is that they are thought to be ``holographically dual" to a quantum field theory which lives in one less dimension and that is heated up to finite temperature.

This is a particular example of what is believed to be a general phenomenon in quantum theories of gravity. But in most examples, one side of the duality is strongly coupled, making explicit computations difficult if not impossible. This obstacle appears to be overcome in holographic duality involving higher spin theories: it is possible to analyze a physical black hole process in the two dual descriptions, which are seemingly completely different. In recent work it was found that the black hole entropy could be matched in this way. Having such a computationally tractable model of quantum black holes should help to resolve some of the notorious paradoxes and puzzles concerning quantum gravity, and should also provide clues to the nature of space-time at the shortest distance scales.

## John M. Cornwall

**John M. Cornwall** continues his research into (QCD) using the pinch technique, a technique invented by him thirty years ago for completely removing the gauge ambiguity otherwise always encountered in constructing off-shell Feynman graphs. He has also been active in explaining how massless quarks ultimately become massive, through QCD forces that confine the quarks into protons and neutrons.

Cornwall, along with his fellow authors **Joannis Papavassiliou** (Cornwall's ex-graduate student, now at the University of Valencia) and Daniele Binosi (Papavassiliou's ex-graduate student, now at ECT* in Trento, Italy) have just published the book "The Pinch Technique and its Applications to Non-Abelian Gauge Theories" (Cambridge University Press, 2011). With his two co-authors and Cristina Auguilar (Sao Paolo) Cornwall organized the very successful International Workshop on QCD Green's Functions, Confinement, and Phenomenology, held at ECT* in September, 2011.


There he spoke on a way, using the pinch technique, to make all off-shell Green's functions of QCD renormalization-group invariant. He has been invited to write a review article based on a recent paper (*Phys. Rev. D 83, 076001 (2011*) and talks, showing how entropy of quark world lines is essential to chiral symmetry breaking through confining forces, as seems to be required in quantum chromodynamics.

## Christian Fronsdal

**Christian Fronsdal** is heavily engaged in two exciting projects:

**What is at the center of the Galaxy?**

There is much talk about Black Holes, but what is known from a great deal of progress in observations, much of it done by colleagues at UCLA, is that there is something very heavy (4.4 solar masses) at the center of our Galaxy. Everything that is needed to study this structure computationally is at hand. Lately one interesting idea is to suppose that the center is dominated by dark matter, and that this dark matter has a very unusual equation of state, possibly with zero entropy. One paper has been submitted for publication.

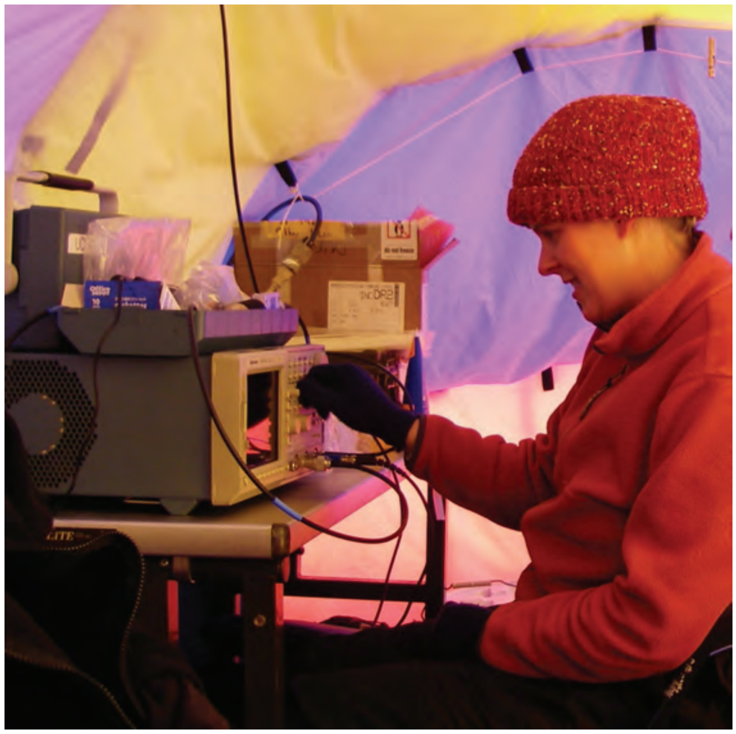
**Thermodynamics**

One ingredient of the Galaxy project is the integration of thermodynamics with General Relativity, this is a problem that Fronsdal claims to have solved. It has been necessary to understand thermodynamics uncommonly well and this has been his main project during some years. This is advancing very well and some of the applications are spectacular, including a much better understanding of the type of atomic dissociation that affects our observation of stars. It is expected that work to be done in the very near future will change the way that stellar atmospheres are evaluated. Another project that well under way is a new study of mixed fluids near the critical point. A monograph on thermodynamics is in the making.

# Astroparticle Physics ANITA Group

## David Saltzberg

**The ANITA group** searches for ultra-high energy particles striking the Antarctic ice. Collaborating with universities around the globe we built a balloon-borne payload that flew for a month at 120,000 feet above Antarctica, viewing over 1 million square kilometers of ice. Most recently, graduate student **Abigail Goodhue Vieregg** searched the data for neutrinos coincident with Gamma-Ray Bursts. Because these bursts are localized in time, the background expectation was reduced to less than a hundredth of an event expected from other processes. Abby analyzed 12 Gamma-Ray Bursts and conducted the first search ever for ultra-high energy (> 1 EeV) coincident neutrinos *[The Astrophysical Journal, 736:50 (2011)]*. Unfortunately, none were seen, but ANITA will fly again in the 2013-14 season.



Abigail Goodhue Vieregg (Ph.D. 2011) taking data in Antarctica in the hunt for ultra-high energy neutrinos with the ANITA experiment.

# Elementary Particle Physics Compact Muon Solenoid (CMS) Experiment

## Katsushi Arisaka, David Cline, Bob Cousins, Jay Hauser, David Saltzberg

This year saw a huge increase in data collection by the **Compact Muon Solenoid (CMS) experiment,** which looks for new physics at the energy frontier using 7 trillion electron-volt collisions of protons accelerated by the Large Hadron Collider (LHC) at the CERN laboratory near Geneva, Switzerland. An exciting search for the Higgs Boson particle, linchpin of the current theory of forces and interactions, is rapidly closing in on finding the particle if it in fact exists (see Figure 1). UCLA **Bob Cousins, and Jay Hauser** have taken major roles in the CMS experiment, as have the research teams of **Katsushi Arisaka, Dave Cline, and David Saltzberg.** Some of the highlights of the year for the UCLA team were:

- Cousins' service as chair of the CMS statistics committee lead to his involvement in the Higgs search, as well as searches in many other areas such as for Supersymmetry.
- Hauser's service as project manager of the CMS endcap muon system while resident at CERN; his term as project manager was recently extended to 2012-2013.
- Research physicist **Greg Rakness'** service as operations manager for the CMS endcap muon system; he was appointed to deputy run coordinator for all of CMS for 2012-2013, and research physicist **Mikhael Ignatenko** will be assuming his current responsibilities.
- Staff scientist **Viatcheslav Valuev** served another year as co-convenor of the muon physics object group.

The UCLA research team has been meanwhile busy with analyzing the flood of new data, especially:

- A search for heavy partners of the Z boson particle earned graduate student **Jordan Tucker** his Ph.D., and was published by the CMS Collaboation and presented by Jordan at the European Physical Society meeting.
- Staff scientist **Valery Andreev** working with one of the UCLA analysis teams has helped produce one of the first CMS papers on Beauty quark production, which is also a test of QCD corrections.
- A search is ongoing for charged particles that are heavy, yet anomalously stable so that they are directly visible in the detector (graduate student **Chris Farrell,** together with Rakness and Hauser).
- Postdoctoral researchers **Amanda Deisher and Charles Plager** measured the cross-section of top quarks with an advanced technique that simultaneously measures the rate of the major backgrounds from W bosons and jets.

New activities have begun with new faces in the UCLA team. Another line of data analysis has begun with the addition of postdoctoral researcher Pieter Everearts, who has begun refining the search for multiple leptons due to Supersymmetry. Meanwhile, under Saltzberg's supervision, new postdoctoral researcher Matthias Weber will create a test station at CERN for new muon detectors that are being built to allow the muon system to keep pace with the ever-increasing rate of proton-proton collisions. Figure 2 shows graduate student Eric Takasugi who worked in a detector-building factory at CERN last summer. Electronics are to be built in the UCLA laboratory for the new chambers and other upgrades under Hauser's supervision.

The UCLA hadron collider group looks forward with anticipation to the discovery of the Higgs particle, either with 2011 data, or with something like three times as much data expected in 2012 running. If the Higgs is not found, then our focus will shift towards finding other mechanisms that have been suggested for giving masses to particles. The new LHC data will, of course, power many other new particle searches.

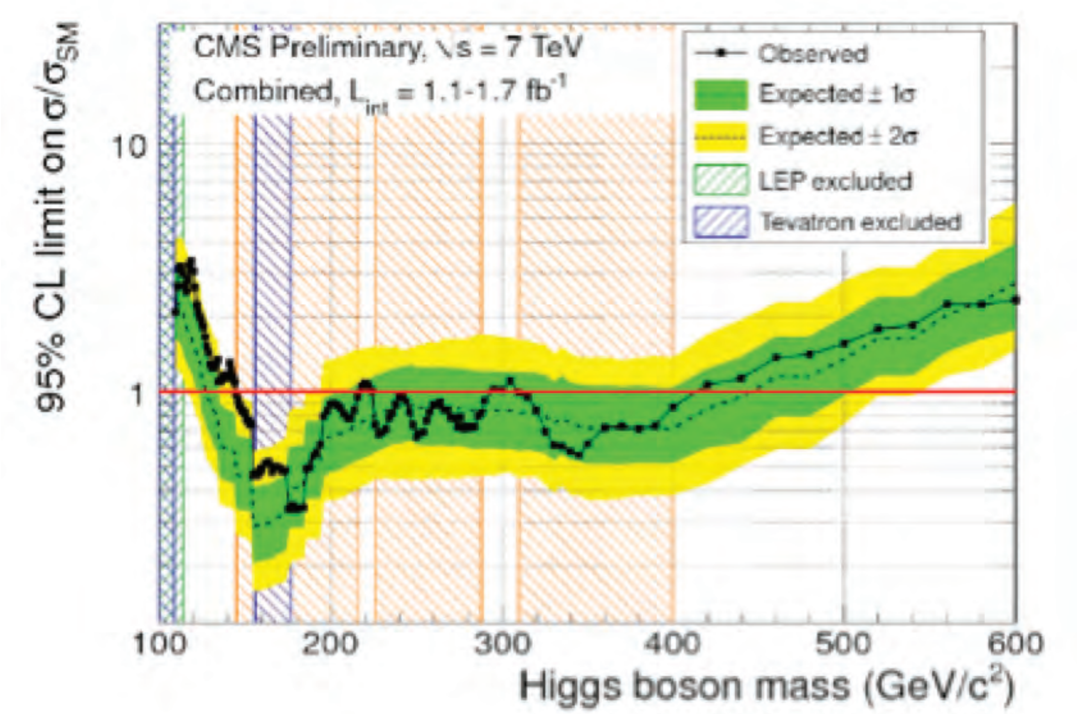



Figure 1: CMS limit (summer 2011) on the hypothetical Higgs particle: where the solid curve representing the upper limit on production rate dips below the line at 1.0 representing expectations, the particle is said to be excluded (at that mass) at 95% confidence level.

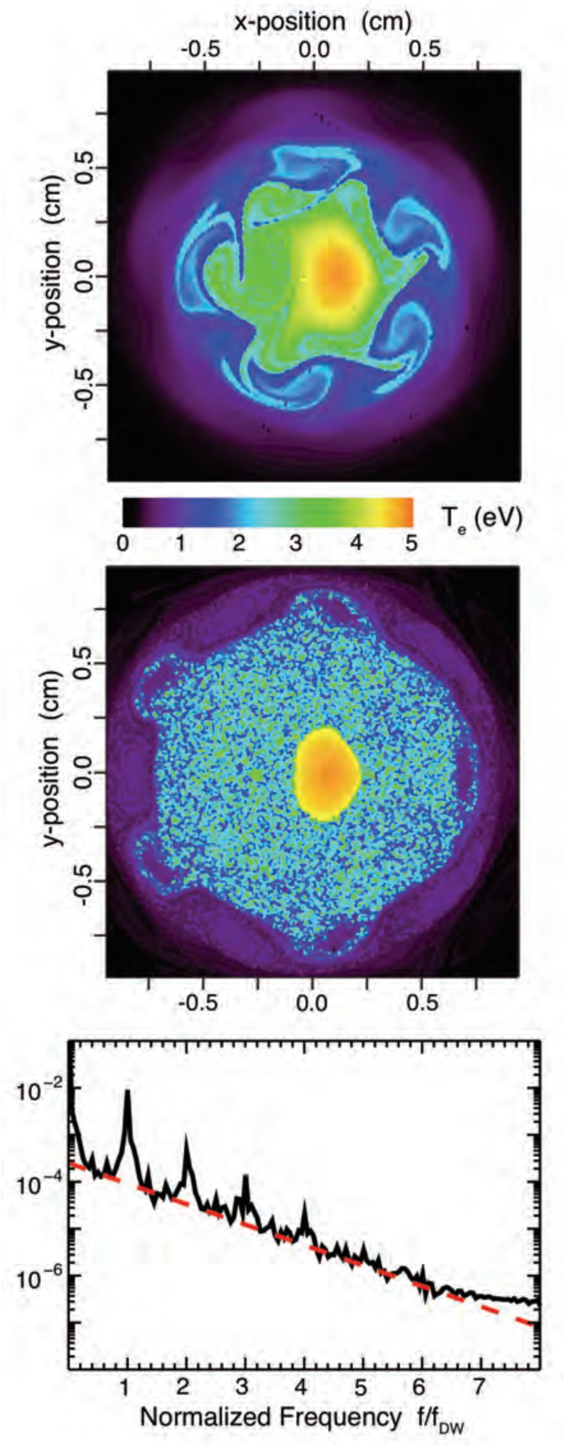
Figure 2: UCLA graduate student Eric Takasugi at CERN putting together parts of a prototype cathode strip chamber chamber.

# Theoretical Plasma Physics:
## George Morales

### Non-Diffusive Transport Project

**George Morales** and **Dr. James Maggs** have developed a collaborative research program on the subject of "Non-Diffusive Transport" with Dr. Diego del-Castillo-Negrete of Oak Ridge National Laboratory (ORNL). They jointly supervise **Adam Kullberg,** a UCLA graduate student. The project has been awarded a three-year grant from DOE/NSF. It consists of basic studies of non-diffusive transport in magnetized plasmas motivated by studies made by Morales and Maggs, together with former graduate students **D. Pace and M. Shi,** in the LAPD device at UCLA. Those studies identified universal features in the spectrum of fluctuations driven by pressure gradients that resulted in non-diffusive energy transport. By non-diffusive it is meant that the transport of fundamental macroscopic parameters of a system, such as temperature and density, does not follow the standard diffusive behavior predicted by a classical Fokker-Planck equation. Contemporary studies in broad areas of science are increasingly identifying the important role of non-diffusive transport. Numerous examples can be found in widely different fields such as biology, geology, atmospheric sciences, and plasma science.

A new perspective has recently emerged from this project that has broad implications for fusion studies. It has been found that, in general, the underlying dynamics of transport in magnetically confined plasmas is deterministic chaos. The connection has been established by demonstrating that a major worldwide survey of experimental observations can be simply explained by a fluctuation spectrum whose frequency dependence is an exponential function, which is the unique signature of deterministic chaos. Deterministic chaos is a nonlinear dynamical state that arises when the amplitude of a few collective coherent modes is sufficiently large to induce chaotic trajectories in the associated phase-space. To concretely illustrate the connection between deterministic chaos and exponential spectra in a magnetized plasma, the figure below presents the results of a simple, two-mode (azimuthal mode numbers m = 1 and m = 6) model of the relaxation of a magnetized temperature filament of the type investigated in LAPD. The amplitude of the m = 1 mode is increased adiabatically before ramping up the m = 6 mode amplitude. The interaction of the two modes leads to chaotic Lagrangian orbits once an amplitude threshold is exceeded. The top panel shows the complex, but spatially connected structures formed when the m = 1 mode is at full amplitude and the m = 6 mode amplitude is just below the threshold for chaotic behavior. The middle panel shows the fine-scale spatial structures that develop after the onset of chaos. The bottom panel is the frequency spectrum of the temperature fluctuations at a time corresponding to the middle panel, showing a clear exponential dependence in a log-linear display, as highlighted by the red dashes. The protruding peaks correspond to the fundamental and first few harmonics of the coherent modes driving the chaos.



# Basic Plasma Science Facility

## Walter Gekelman

**The Basic Plasma Science Facility** hosts users from throughout the United States. There is no space in this report to enumerate all the experiments (there are over 20 of them, all very different). One fascinating one has been the destruction of a high energy (100 eV < E < 5 MeV) electron ring trapped in a magnetic mirror. A shear Alfvén wave has been observed to de-trap these electrons. This is a key experiment on radiation belt physics. It is the thesis topic of **Yuhou Wang** supported by **Walter Gekelman and Pat Pribyl** at UCLA and involving Dennis Papadopoulos and others at the University of Maryland. Lately other radiation belt experiments involving Pat Colestock from Los Alamos, Bart Van Comperolle, Gekelman, Pribyl form the plasma lab. The radiation belt is a region in space between 1-3 earth radii where plasma is trapped by the earth's magnetic field. It is also the place where most valuable communications satellites reside. Another series of radiation belt experiments with Jacob Bortnick from UCLA Earth and Space Science, one of his postdocs and the UCLA started about a year ago. This involves the scattering of electrons by whistler waves. The plasma group has become the worlds premier facility for studying radiation belt physics in the lab.

Theoretical calculations have indicated that in magnetized plasmas with two ion species, Alfvén waves, oscillations of the magnetic field due to plasma currents, can become trapped in a resonator. Now such a resonator has been demonstrated for the first time in a laboratory. Working together, **Stephen Vincena, William Farmer, James Maggs and George Morales** created the resonator in a magnetized plasma with hydrogen and helium ions, in UCLA's LAPD. Their observations agreed well with theoretical predictions. Similar resonators could occur in the magnetosphere around Earth and other planets, where the resonant modes can interact with energetic particles. Vincena will give an invited presentation on this topic at this year's annual APS Division of Plasma Physics meeting.

Gekelman, **Nathaniel Moore**, Pribyl and **Mio Nakamoto** have been using Laser Induced Fluorescence to measure the ion distribution function of Argonions plunging towards an RF biased wafer in a plasma processing tool. A sheet of laser light was used and the distribution function measured at The meaurement show a highly non Maxwellian distribution with ions up to 600 eV in the RF sheath. The measurement has 0.4 mm resolution. The time resolved measurement is the first of its kind and Gekelman has an invited paper at the GEC conference (coincident with the APS-DPP meeting).

We next report in some detail an ongoing study of magnetic flux ropes. Magnetic flux ropes are regions of helical magnetic field lines with pitch varying with radial position from the center of the spiraling currents that cause them. Magnetic flux ropes exist in the solar corona where they form enormous arches and have been recorded in the Earth's magnetotail and near other planets. If two or more flux ropes move toward or away from one another magnetic field line reconnection can occur locally. This has been observed by **Eric Lawrence** (who graduated last spring and Gekelman) when two ropes undergoing reconnection were immersed in a background magnetoplasma. The studies are being continued by Gekelman and Bart Van Compernolle, and Pat Pribyl research scientist who are studying 3 or more ropes and the break up of a sheet of current into them. The method of production is shown in figure 1. The method of production involves masking a high emissivity cathode carbon into which holes or slots are formed.

The kink instability, makes the ropes thrash about is readily seen in optical emission and was used as a temporal fiducial, necessary as the experiment was repeated several hundred thousand times. The presence of reconnection is apparent with the formation of Quasi-separatrix layers (QSL, also called slip squash factors). QSL's were introduced by solar physicists to determine where regions of reconnection occur in complex, 3D magnetic field geometries. Essentially if two neighboring field lines traverse a region where magnetic reconnection occurs (and the field topology is changing) would then veer away from one another. The mathematical expression for the QSL is given in reference 1, but the LAPD group has measured them experimentally for the very first time. The image in figure 1 encapsulates much of the experiment but is best appreciated in true 3D.

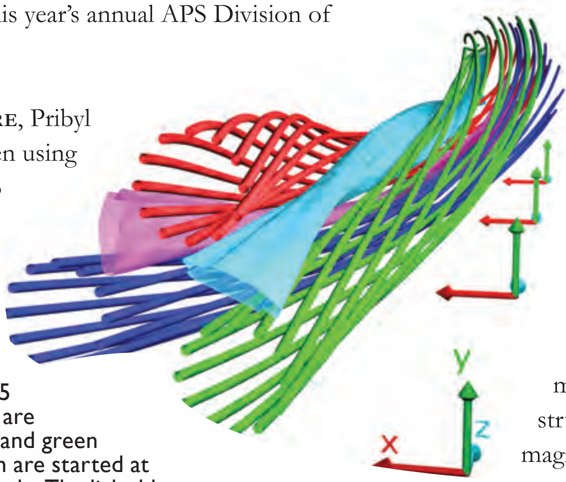
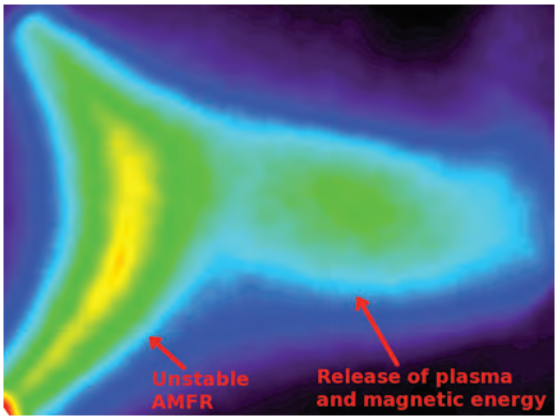



Fig.1. Data rendered from the 3 flux rope experiment. Data was acquired at 32,400 spatial locations throughout a volume 9.58 min length. (dt = 0.64 ms, Tacquire = 5.5 ms). The coordinate axes displayed are each 2 m apart. The red, dark blue and green tubes are magnetic field lines, which are started at the edge of the three current channels. The light blue and pink transparent surfaces are Quasi-Separatrix layers derived from the data (Q=19). The flux ropes are kink unstable and when they collide QSL's appear, sometimes there is one, other times such as this there are two or more. When the ropes move away from one another, the QSL disappears.

Solar flares are sudden, rapid, and intense brightening on the sun that occur due to impulsive release of the magnetic energy stored in the arched shaped plasma structures. These arched structures are called arched magnetic flux ropes (AMFRs) since they carry electrical current which generates a "rope" like twist in the magnetic field. Coronal loops and prominences are the main examples of solar AMFRs. It is believed that under certain conditions, these AMFRs can become unstable and drive solar flares. These are




Generation of a loop flare in a laboratory plasma experiment at the Basic Plasma Science Facility. These loop flares are produced with a precise control over the background conditions and they capture the essential physics of actual solar loop flares that are millions of times larger.

extremely intense explosions on the sun that release up to 1026 joules of energy certain conditions, these AMFRs can become unstable and drive solar flares. These are extremely intense explosions on the sun that release up to 1026 joules of energy (amounting to ten million times greater energy than a volcanic explosion). Solar flares can strongly influence the earth's space weather by driving geomagnetic storms and they present radiation hazards to space crafts and astronauts. Since the spacecrafts rely on the remote monitoring and detection of such energetic events, carefully scaled laboratory plasma experiments can play a crucial role by identifying the important microphysics related to the dynamics of flares by direct measurement of parameters and precise control over boundary conditions.

Two researchers from the Basic Plasma Science Facility - **Shreekrishna Tripathi** and Walter Gekelman - have devised a laboratory plasma experiment that generates "loop flares" within confines of a large cylindrical vacuum chamber (4.0 m long, 1.0 m diameter). The laboratory loop flares are generated in three steps – (i) an AMFR with a persistent appearance is produced using a hot LaB6 cathode and two electromagnets placed inside the vacuum chamber, (ii) two laser beams are fired simultaneously to ablate carbon rods that trigger the AMFR instability by producing intense flows from the AMFR foot-points, and (iii) the AMFR dramatically erupts in the ambient plasma produced by another source. This sequence is repeated with a 1/2 Hz repetition rate and several thousands of identical laboratory loop flares are routinely generated. Computer controlled movable probes (e.g., Langmuir probes, three-axis magnetic loop probes, energy analyzers) and a fast CCD camera are the main diagnostic tools. Initial studies on this experiment have been focused on the role of the magnetic flux and plasma injection in triggering the AMFR eruption and excitation of fast-magnetosonic waves following the eruption. These results have been published [5] in Physical Review Letters and have drawn attention of several print and online media. This experiment has also generated interest in solar physics community and collaborative efforts are expected in this cross-disciplinary area of research in near future.

## Troy Carter

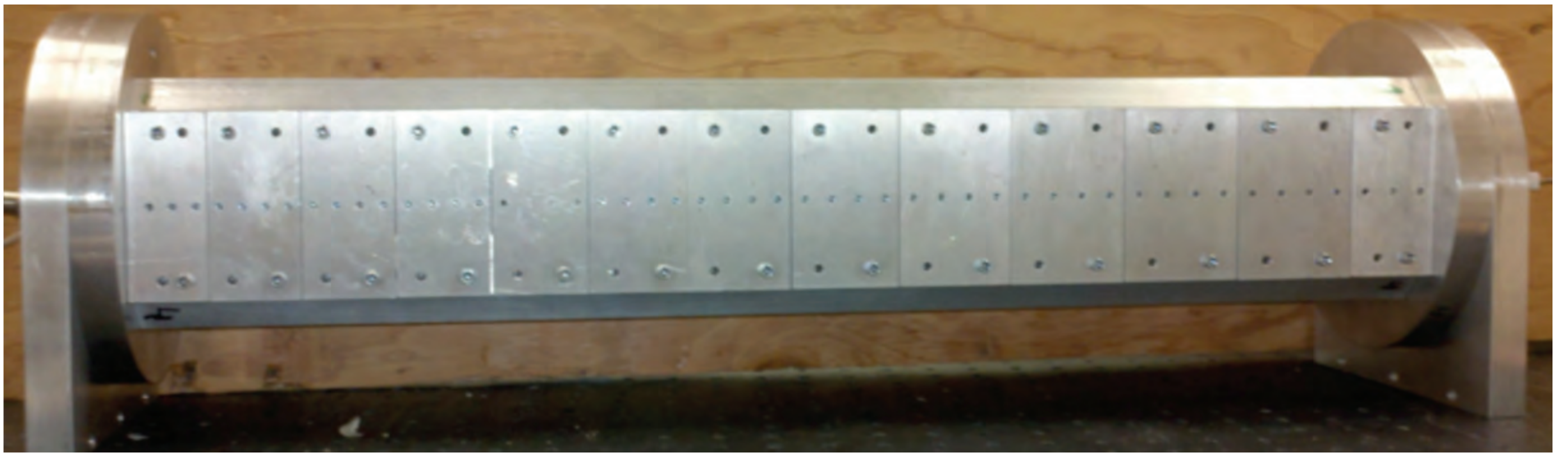
**Troy Carter** has continued work on nonlinear processes, turbulence and transport in magnetized plasmas. His work makes use of the Basic Plasma Science Facility (BAPSF) at UCLA as well as magnetic confinement fusion research facilities such as the DIII-D tokamak (General Atomics) and the National Spherical Torus Experiment (Princeton). Drift waves and drift wave turbulence are responsible for transport of heat, particles and momentum across the confining magnetic field in laboratory devices including fusion experiments. This transport limits the confinement time of fusion devices, making it more difficult to achieve the conditions needed for production of net fusion power. Carter's recent work has focused on understanding and controlling these waves and the associated turbulence and transport. Graduate student **David Auerbach** recently completed his thesis work investigating nonlinear interactions between Alf\'{e}nwaves and drift waves. David showed that drift waves can be nonlinearly controlled when two higher-frequency Alfv\'{e}n waves beat together to drive a response near the drift wave frequency. His work may lead to the ability to control turbulence and transport in fusion devices using externally launched radiofrequency waves. It was first demonstrated at UCLA by Bob Taylor in the late 80's that driven flow can lead to enhanced confinement in tokamak plasmas, helping to explain the spontaneous transition to high confinement (H-mode) at high power in tokamaks. The mechanism behind the transport change with flow has been linked to flow shear, but many open questions remain. Carter, UCLA researcher **Jim Maggs,** graduate student **David Schaffner,** and undergraduate students **Giovanni Rossi and Danny Guice** are working on understanding the influence of driven flow and flow shear on turbulence and transport in the Large Plasma Device (LAPD) at UCLA. For the first time, experimental data has been gathered showing the detailed variation of turbulence characteristics and particle flux with flow shearing rate, showing that the flux drops systematically with increasing flow shear and is insensitive to the direction of the radial electric field. Modeling of these experiments using massively-parallel plasma turbulence simulation codes has been carried out by graduate student **Brett Friedman,** in collaboration with LLNL scientist **Maxim Umansky**. Good qualitative and semi-qualitative agreement has been found using a two-fluid plasma model, but future efforts will seek to incorporate additional physics into the models and test large-scale kinetic plasma simulation codes being developed in the fusion community.

# Particle Beam Physics

## Pietro Musumeci

**The Pegasus photoinjector Laboratory** led by **P. Musumeci** stays at the forefront of the generation diagnosis, manipulation and applications of high brightness ultrashort electron beams. Thanks to a newly developed high spatial resolution detector with single electron sensitivity *(R. Li, P. Musumeci et al. Journal of Applied Physics 2011),* the laboratory was able to start a detailed campaign in the measurement of very low charge beams. Such beams do not carry many electrons, but the phase space densities (and so the beam quality) achieved can be far superior than higher-charge, more traditional beams, opening new exciting applications in electron microscopy and advanced accelerators. In particular they also are ideal candidates to study and exploit collective instabilities like the longitudinal space charge or the free-electron laser instability.

UCLA also maintains the world-wide leading role in Inverse free-electron laser research activities. IFEL, the inverse process of the better known free-electron laser (FEL) mechanism can be used to extract energy from the radiation (typically a high power laser beam) to accelerate particles with very high gradients. Two ongoing experiments are currently led by UCLA graduate students. One, called the RUBICON IFEL project is scheduled to have beamtime at the Accelerator Test Facility at BNL starting in the Winter of this year and uses for the first time a helical strongly tapered undulator that was designed and built here at UCLA to accelerate particles from 50 MeV to 120 MeV using a 0.4 TW CO2 laser system. The other experiment will break the record for highest laser power used in an IFEL experiment and will accelerate 50 MeV to 160 MeV in 50 cm using 4 TW of Ti:Sa 800 nm laser light.



The UCLA helical strongly tapered undulator for the RUBICON IFEL acceleration experiment at BNL.

## Gil Travish

**Gil Travish** and his team are working on advanced accelerators and new radiation sources. This past year has seen the transformation of ideas and simulations on a novel "particle accelerator on a chip" into reality. Gil's postdoc, **Jianyun Zhou,** has spent the past two year's in the clean rooms on-campus at the CNSI and Engineering School turning designs into fabricated structures.

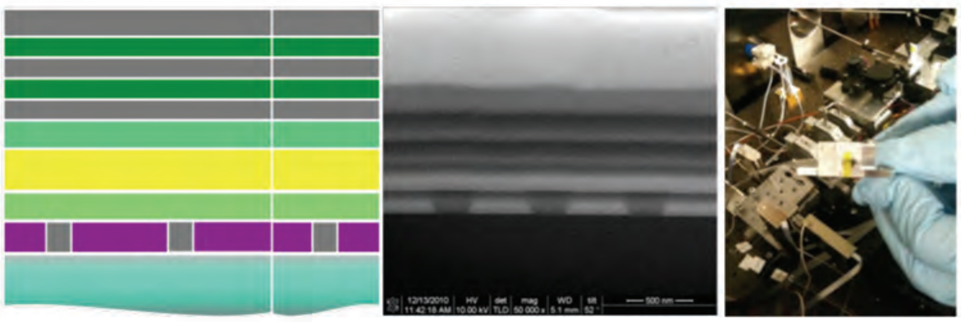


Figure: A design of the MAP structure showing various material layers (left); a scanning electron microscope image of a fabricated structure (middle); a test structure being installed in an accelerator beamline for testing (right).

Prototype structures are now undergoing tests at an accelerator facility at SLAC. These tests should prove to be the first proof of particle acceleration in an optical scale structure. Tests this past year have already shown that electrons traversing the one-optical-wavelength (800 nm) high gap in the structure can be distinguished from those electrons which missed the gap.

Graduate student **Josh McNeur** continues to perform detailed numerical simulations of the beam dynamics and electromagnetic response of the structure. Staff member **Esperanza Arab** has begun investigating more exotic variations of the MAP structure for use in proton and other heavy particle acceleration. Undergraduates **James Allan, Nestor Carraza, Ritika Dusad, and Alexander Lin** continue on related research projects in beam and radiation production. They were joined by Chad Germany from UC Berkeley this past summer who participated in the department's REU program

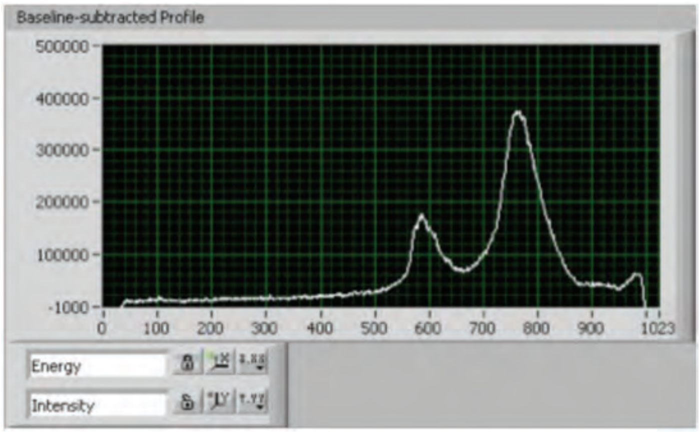



Figure: Particle momentum is plotted as a function of intensity detected on a bend spectrometer in the particle accelerator. The smaller peak near the middle of the trace shows particle which passed through the middle gap of the test structure; the larger peak on the right of the trace shows particle which lost energy due to collision with the (glass) structure itself.

## James (Jamie) Rosenzweig

**Prof. James Rosenzweig,** the director of the UCLA Particle Beam Physics Laboratory, has begun a number on new initiatives during the last year in advanced accelerator and light source research. His group has commenced new experiments at the FACET laboratory at SLAC, on gigavolt per meter wakefield acceleration. He has also received a new grant from DARPA to fund a multi-institute collaboration for over $7M in the coming 4 years, termed GALAXIE (GV/m AcceLeration And X-ray Integrated Experiment). Leveraged off the development of a new 5 micron wavelength laser source, GALAXIE aims to produce a table-top high energy electron accelerator and X-ray. free-electron laser using all-optical techniques.

# The Computer Simulations of Plasma Group

## Warren B. Mori, Adjunct Professors Viktor Decyk, and Phil Pritchett

**The Computer Simulations of Plasma Group** *(http://plasmasim.physics.ucla.edu)* under the leadership of **Warren B. Mori,** and **Adjunct Professors Viktor Decyk, and Phil Pritchett** continues to do pioneering work in high-performance computing of complex plasma phenomena. The group also currently includes three research physicists (**Dr. Tsung, Tonge, and Lu**), two post-doctoral researchers, and six PhD students. Its research remains focused on the use of fully parallelized particle based simulation models to study laser and beam plasma interactions, space plasmas, Alfvenic plasmas, and high-energy density science. The group specializes in particle-in-cell (PIC) techniques and continues to develop and maintain over five separate state-of-the-art PIC simulation codes, OSIRIS, PARSEC, Magtail, QuickPIC, and the UPIC Framework. These codes are used throughout the world and are run on as many as 300,000 processors on some of the world's fastest computers.

The Simulation of Plasma Group with support from the UCLA Institute for Digital Research and Education received a $1.8 million Major Research Instrumentation (MRI) Award from the National Science Foundation (NSF) to build a compute cluster based on General Purpose Graphics Processing (GPGPU) units. This cluster was ranked 148th in the Top 500 list and is the largest computer in the UC system. It is also in the top 10 of the most "green" computers where computers are ranked by how my Watts they use per floating point operation. This cluster is dedicated to high energy density plasma research. A picture of DAWSON2 is shown in Figure1.

One of the group's codes, OSIRIS, was chosen by the Department of Energy (DOE) to be part of their Office of Advanced Scientific Computing Research software effectiveness program. The group is also part of a recently awarded a new NSF Collaborative Research Grant on "Graduate Student Training Through Research on Plasma-Based Accelerators." In the past year, the group also received several new Innovative and Novel Computational Impact on Theory and Experiment (INCITE) Awards that provides access to the largest computers managed by the Department of Energy (DOE). The Awards are in plasma-based acceleration and in Laser-plasma coupling for inertial fusion energy. The group also continues to be affiliated with DOE Scientific Discovery through Advanced Computing (SciDAC) grant titled,

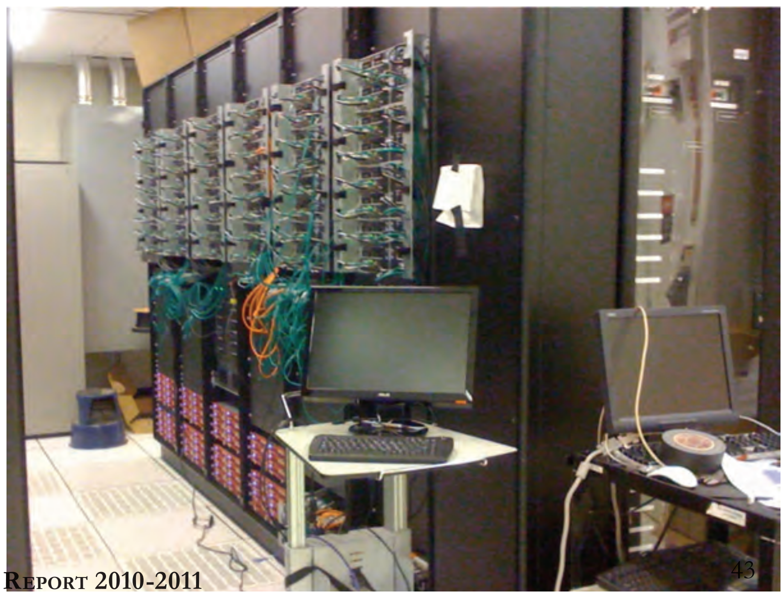


Fig 1: The DAWSON2 Cluster

"Community Petascale Project for Accelerator Science and Simulation" (COMPASS), as well as a DOE Fusion Science Center (FSC) on "Extreme states of matter and fast ignition physics".

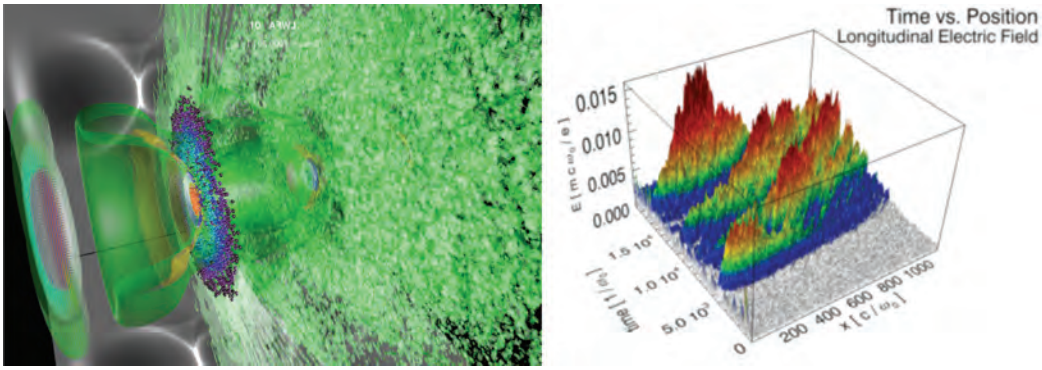



Figure 2: (left) The laser, the plasma wake, and accelerated electrons from an OSIRIS simulation run on the full Jaguar computer. (right) The evolution in time of the plasma wave amplitude along x generating by stimulated Raman scattering.

The group has also made great strides in research in plasma based accelerators, in laser-plasma interactions regarding inertial confinement fusion, regarding the fast ignition ICF concept, in laser driven collisionless shocks for generating mono energetic ion beams and for studying astrophysical like shocks in the laboratory. Sample results are shown in figure2. During the past year the groups results have been published (http://plasmasim.physics.ucla.edu) in NaturPhysics, Physical Review Letters, Physical Review E, Physical Review STAB, Physics of Plasmas, Plasma Physics and Controlled Fusion.

# Space Plasma Simulation Group (SPSG)

## Maha Ashour-Abdalla

**Maha Ashour-Abdalla** heads the **Space Plasma Simulation Group (SPSG)**, which includes five senior researchers (**Jean Berchem, Mostafa El Alaoui, Vahe Peroomian, Robert Richard and David Schriver)** and two graduate students (**Jodie Ream and Qingjiang Pan**).

Progress has been made in understanding physical processes involved in the acceleration of electrons and ions during magnetospheric substorms, which has long been one of the key unsolved problems in space plasma physics. We have used MHD and large scale kinetic particle simulations along with observations from the Cluster and THEMIS missions to investigate the dynamics of electrons that are found associated with earthward propagating dipolarization fronts, which are increases in the north-south component of the Earth's magnetic field earthward of the neutral line. It was revealed that the physics of the electron acceleration can be described as a two-step process involving both reconnection and betatron acceleration, with excellent agreement between theory and observations. Figure 1 highlights these results, which are described in a recently published article in Nature.

Advancement has also been made in understanding Mercury's magnetosphere using a first of its kind global hybrid simulation that fully resolvse each ions' gyro-radius. This research effort provides theoretical support for the MESSENGER spacecraft mission, which became the first orbiter of Mercury upon successful insertion in March 2011. A new result predicted from the simulations and supported by the observations made in orbit by MESSENGER is that Mercury has a quasi-trapped, equatorially centered plasma population around it, akin to the Earth's ring current and radiation belt. The energy of Mercury's quasi-trapped population, however, is much lower compared to Earth's trapped particle populations Previously it was thought that Mercury's magnetosphere was too small to support a trapped population. The figure 2 taken from a recently submitted manuscript to Geophysical Research Letters shows the excellent agreement between MESSENGER observations and the hybrid simulations.

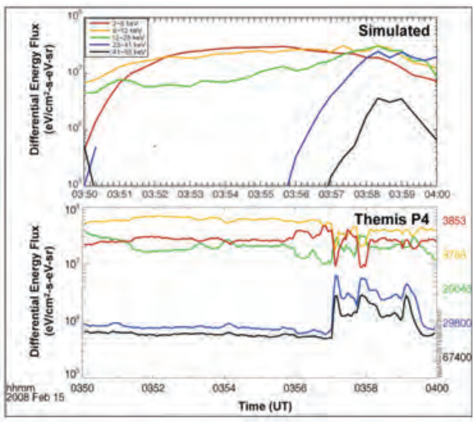



Figure1: Simulated energy fluxes and observed energy fluxes from THEMIS P4 observations. The energy channels for the simulation are given in the upper left corner. The energy channels for the observations are given by the scale on the right.

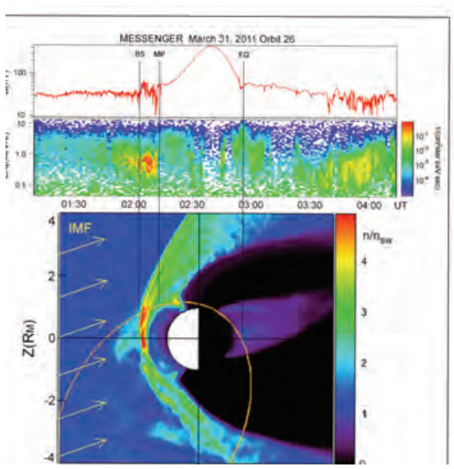



Figure 2. The top two panels show about 3 hours of data from MAG and FIPS on the MESSENGER spacecraft for Mercury orbit 26 on March 31, 2011, respectively, and the bottom panel shows contours of ion density (normalized to solar wind density) from a global hybrid simulation in the noon-midnight meridian (z-x plane, y = 0). Superimposed on the simulation contours is the MESSENGER orbit in gold; the arrows at left show the orientation of the IMF. The bow shock (BS), magnetopause (MP), and nightside equatorial (EQ) locations are indicated.

# Faculty, 2010-11

## Professors
Elihu Abrahams (Adjunct)
Katsushi Arisaka
Maha Ashour-Abdalla
William Barletta (Adjunct)
Zvi Bern
Stuart Brown
Robijn Bruinsma
Sudip Chakravarty
David Cline
Ferdinand V. Coroniti
    Associate Dean of Physical Sciences
Robert Cousins
Eric D'Hoker
Sergio Ferrara
Christian Fronsdal
Walter Gekelman
Graciela Gelmini
Andrea Ghez
George Grüner
Brad Hansen
Jay Hauser
Kàroly Holczer
Huan Huang
David Jewitt
Hong-Wen Jiang
Michael Jura
    Vice Chair of Academic Affairs
Per Kraus
Alexander Kusenko
James Larkin
Matthew Malkan
Thomas Mason
Ian McLean
    Vice Chair of Astronomy and
    Astrophysics
Jianwei Miao
George J. Morales
Warren Mori
Mark Morris
William Newman
Rene Ong
C. Kumar N. Patel
Roberto Peccei
Seth J. Putterman
James Rosenzweig
    Department Chair
Joseph A. Rudnick -
    Dean of Physical Sciences
David Saltzberg
    Vice Chair of Resources
Reiner Stenzel
Terry Tomboulis
Jean Turner
Rainer Wallny
Charles A. Whitten
Gary A. Williams
Edward Wright
Giovanni Zocchi

## Associate Professors
Troy Carter
Steven Furlanetto
Michael Gutperle
Jean-Luc Margot
Mayank Mehta
Jianwei Miao
Thomas Mason
Alice Shapley
Yaroslav Tserkovnyak
Vladimir Vassiliev

## Assistant Professors
Dolores Bozovic
Michael Fitzgerald
Eric Hudson
Pietro Musumeci
Christoph Niemann
B. Chris Regan
Martin Simon (Adjunct)

## Professors Emeriti
Ernest S. Abers
Eric Becklin
Rubin Braunstein
Charles Buchanan
Nina Byers
Marvin Chester
Gilbert W. Clark
John M. Cornwall
Robert Finkelstein
Roy Haddock
George Igo
Leon Knopoff
Steven Moszkowski
Bernard M. K. Nefkens
Claudio Pellegrini
William E. Slater
Roger Ulrich
Alfred Wong
Chun Wa Wong
Eugene Wong
Byron T. Wright
Benjamin Zuckerman

# Researchers, 2010-11

## Researchers
Viktor Decyk
Weixing Ding
Samim Erhan
James Maggs
William Peebles
Philip Pritchett
Terry Rhodes
R. Michael Rich
Lothar Schmitz
Gil Travish
Steven Trentalange
Manuel Urrutia
Hanguo Wang

## Associate Researchers
Mikhail Ignatenko
Frank Tsung
Stephen Vincena

## Assistant Researchers
William F. Bergerson
Carlos Camara
Carmen Constantin
Neal Crocker
Xiaoping Ding
Atsushi Fukasawa
Liang Lin
Wei Lu
Sebastiaan Meenderink
Leonhard Meyer
Brian Naranjo
Shoko Sakai
Alexsandr Starostin
John Tonge
Shreekrishna Tripathi
Bart Van Compernolle
Gang Wang
Jeffrey Zweerink

IN MEMORIAM

## CHARLES ALEXANDER WHITTEN, JR. 1940 - 2010



Charles Alexander Whitten Jr. was born on January 20, 1940. He was educated at Yale University where he received his B.S. degree in 1961 (summa cum laude) and received his M.A. (1963) and Ph.D. (1966) at Princeton University. Following his post-doc years at Yale, he came to UCLA as an Assistant Professor in 1968.

Professor Chuck Whitten unexpectedly passed away on Saturday morning, December 4, 2010. He was preparing his final exam on that Saturday morning. He enjoyed teaching physics and was doing that until the last moment of his life.

Chuck's voice in the hallway, his passion for experimental details including the accelerator operations, his exploration of exotic cuisines and his friendliness to students, in particular foreign students working on our experiment, are legendary in the collaboration. Chuck was the father figure in the nuclear physics group. He attended students' hooding and graduation ceremonies.

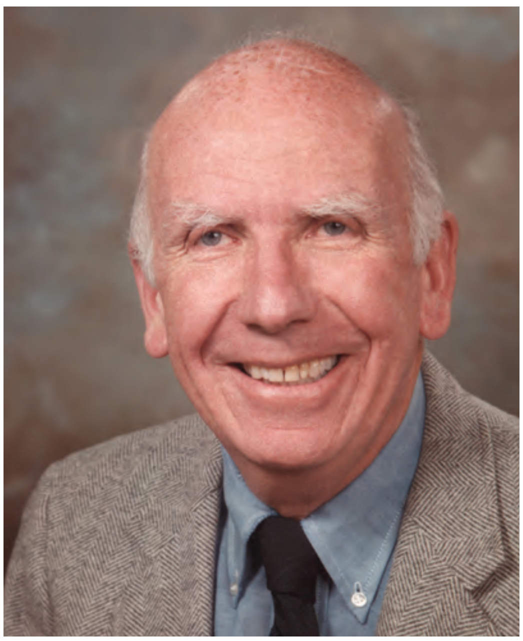
Chuck would not hesitate to express his opinions, especially when he was in disagreement on issues. Over the years he had his share of arguments with the administration, colleagues and collaborators and he was often passionate in making his arguments. Despite his outspoken nature he was universally well respected and remained a beloved colleague to people who crossed paths with him. His devotion to the Physics & Astronomy Department, to UCLA, and to the experimental collaborations was so apparent that there was no question about his motivations even when he was in disagreement on issues.

Chuck had a unique way to make people feel a part of his family. He treated everyone with respect and kindness. He made friends with everyone on campus, including research staff, technical staff, administrative staff, building support staff and service staff. He was the glue that bound us together as an extended family at UCLA. We are saddened that we lost a dear family member with Chuck's passing. We cherish the memory that Chuck left us.

Chuck is survived by his wife Joan, son Alec, daughter-in-law Jennifer (Bontrager) Whitten beloved grandchildren Calder and Branwen.

A fund has been set up in the name of Charles A. Whitten Jr. Memorial Fund to provide scholarships to deserving teaching assistants in the Department of Physics and Astronomy. Contact Kerri Yoder, UCLA Director of Development, Physical Sciences Division, 1309 Murphy Hall, Box 951413, Los Angeles, CA 90095-1413.

## LEON KNOPOFF 1925 - 2011



Professor of Physics and Geophysics, Leon joined the UCLA faculty more than 60 years ago, in 1950. He was known for his extraordinary intellect and for his delight in sharing his knowledge and in exchanging ideas. He was a gifted educator who took great joy in teaching and in seeing his students develop into scholars.

Leon was an internationally renowned scientist who was extremely creative and prolific. With his students, postdocs, and colleagues, he made significant and pioneering discoveries in a wide variety of fields, including fundamental geophysics, nonlinear earthquake dynamics, earthquake statistics, music as a complex system, and even archaeology. His publications number more than 365, and many demonstrate his endearing sense of humor.

In 2000, UCLA's IGPP honored Leon's 75th birthday and his 50th anniversary at UCLA with a symposium entitled "The Earth: Earthquakes and Seismic Waves." The symposium led to publication of a Festschrift volume in his honor.

A man with broad interests, Leon had a deep love for and encyclopedic knowledge of classical music. He played piano and harpsichord and for many years hosted chamber music sessions at home. His backpacking expeditions in the Sierra Nevada and in mountains in far-flung parts of the world were among his happiest times. Cherished only child of Max and Ray Knopoff, Leon was born in Los Angeles and was the first of his family to attend college.

Leon is survived by his wife, Joanne, and his children, Katie, Rachel, and Michael.

Memorial donations can be made to the Leon & Joanne V.C. Knopoff Fund, an endowment for a career development chair for a young scientist at UCLA. Checks should be made payable to the UCLA Foundation with a memo note for the Leon & Joanne Knopoff Fund #9395. Checks can be sent to Kerri Yoder, UCLA Director of Development, Physical Sciences Division, 1309 Murphy Hall, Box 951413, Los Angeles, CA 90095-1413.

# Department News

## Retirement

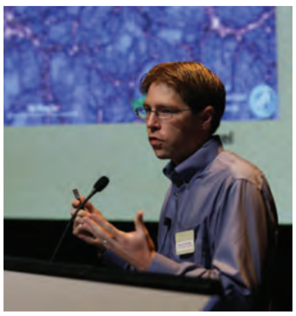
Professor Claudio Pellegrini retired last year from UCLA. He now works part-time at SLAC on improvements to future free-electron lasers (FELs). Claudio was the first person to propose that the SLAC Linac Coherent Light Source (LCLS) use an electron beam to generate extremely bright, intense, coherent X-rays—much like a laser does for visible light. This revolutionary new device which can be used to image single molecules, using the unique properties of coherence.

Pellegrini is presently working to ensure that SLAC becomes a world-wide facility for research and development. Linac Coherent Light Source (LCLS) is now so busy that to take the time to test new ideas would be too difficult. Having a dedicated facility for FEL studies is needed to push the FEL to its maximum capacity.

Thus, in addition to working on some general aspects of FELs, Professor Pellegrini is working to help push a proposal to build a facility dedicated to FEL studies and ideas. This idea has been endorsed by SLAC's Scientific Policy Commission.
*https://news.slac.stanford.edu/features/claudio-pellegrini-patriarch-lcls*
The department wishes Claudio Pellegrini a happy retirement as he continues his path-breakingwork with FELs.

## Awards


Edward L. (Ned) Wright, was elected to the prestigious National Academy of Sciences "in recognition of distinguished and continuing achievements in original research." Wright, a professor of physics and astronomy who holds the UCLA's David Saxon Presidential Chair in Physics, is among the most-cited researchers in the field of cosmic microwave background radiation. He is principal investigator for NASA'S Wide-field Infrared Survey Explorer (WISE) mission, an unmanned satellite that has surveyed the entire sky to discover millions of uncharted stars and galaxies, asteroids, and other ojects, providing valuable new information on our solar system, the Milky Way and the universe. For more on the WISE mission, visit *http://wise.astro.ucla.edu*. Ned has also been invited to join the Physics Section as a secondary affiliate, in addition to his primary membership in the Astronomy Section.



Steven Furlanetto was awarded the AAS 2011 Helen B. Warner Prize for his theoretical work in the field of high-redshift cosmology, including ground-breaking work on the epoch of reionization and its observational signatures, opening up new pathways to the study of reionization in the redshifted 21-cm hydrogen line.

Martin Ammon Awarded Otto Hahn Medal. Post-doctoral researcher, Martin Ammon, was awarded the "Otto Hahn Medal" by the Max Planck Society. It is given to young scientists and researchers in both the natural and social sciences. The prestigious award takes its name from the German chemist and Nobel Prize laureate Otto Hahn, The medal is awarded annually in recognition of outstanding scientific achievement to junior scientists. Medalists are recognized in three thematized sections: Biological-Medical section, Chemical-Physical-Engineering section, and Social Science-Humanities section. It is awarded annually at a ceremony taking place in Germany and is accompanied by a monetary award.

The Keck Foundation granted $1M over 3 years, to fund a proposal by Mayank Mehta (PI) and Katsushi Arisaka (co-PI) entitled "Neurophysics of Multi-modal Integration and Neural Representation of Space". This winning of such an extremely competitive award is another indication of the rapid rise of the departmental program in neurophysics in particular, and biophysics in general.

# FACULTY INVITED TALKS

Prof. Zvi Bern gave a layman's account of the modern view of Feynman diagrams at the recent TEDxCaltech celebration of Richard Feynman's vision. Zvi Bern's primary interest is in developing new methods for calculating and understanding scattering amplitudes. He is especially interested in applications to LHC physics and to maximally supersymmetric gauge and gravity theories. To get an overview of his research you can watch the video, TEDxCaltech: "Feynman Diagrams: Past, Present, Future."

Andrea Ghez was the featured speaker at "Carnegie Captial Science Evening Lecture Series"
*http://carnegiescience.edu/events/lectures/galactic_center_uncovering_pulse_our_galaxy*
Ghez also was the Sackler Distinguished Lecturer in Astronomy at UC Berkeley
*http://events.berkeley.edu/?event_ID=38462&date=2011-03-30&tab=lectures*

Seth J. Putterman, was the 109th Faculty Research Lecturer. On November 30, 2010, he presented his lecture "Fiat Lux: Light from Gas Bubbles, X-Rays from Peeling Tape, and Fusion from Crystals" The biannual Faculty Research Lecture at UCLA presents the work of the university's most distinguished scholars. Its purpose is to recognize their superb achievements, and give the campus and the greater community an opportunity to gain a new perspective on scholarly achievements and the viewpoints of the faculty honored.The Faculty Research Lecture, Putterman acknowledged, is quite an honor. " There's nothing to compare to it in my career,"
Putterman's Faculty Research Lecture can be accessed at *http://www.oid.ucla.edu/Webcast/frl/putterman*

Scientists at a meeting in Grenoble, France, stoked speculation recently that physicists at the world's biggest particle accelerator may soon provide a first look at the elusive Higgs boson — the final piece of evidence needed to prove that the Standard Model of particle physics, which explains the behavior of subatomic particles, is correct.

The $10-billion Large Hadron Collider was built near Geneva by the European Organization for Nuclear Research, or CERN, to create exotic particles that physicists believe existed in the moments after the Big Bang. For the last 14 months, it has been hurtling beams of protons toward each other around a roughly 17-mile track at nearly the speed of light.

UCLA physics professor Robert Cousins has worked on the collider's Compact Muon Solenoid detector since 2000. He talked with The Times from his office at CERN in Geneva about the quest for the Higgs boson. To read the Q & A with Cousins go to
*http://articles.latimes.com/2011/aug/01/science/la-sci-higgs-boson-qa-2011080*

# DEPARTMENT OUTREACH & EDUCATION NEWS

## Astronomy Live!


**Bruin Heroes Award, May '11 – Astronomy Live!**

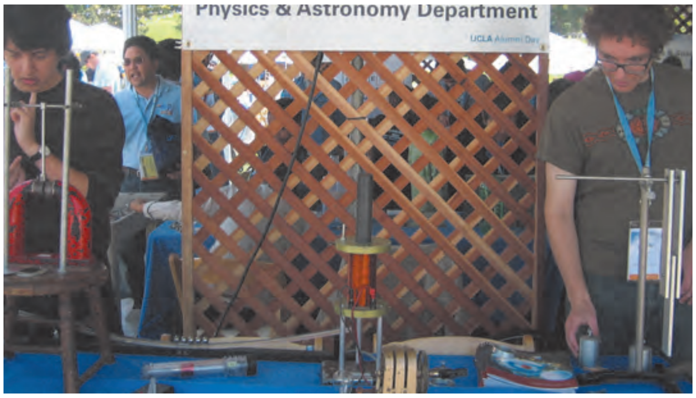
UCLA's astronomy outreach program, Astronomy Live!, is entering our third year of graduate student led community outreach. During the 2010-2011 school year, we visited five different elementary schools throughout Los Angeles county and coordinated a visit to UCLA for ~100 students from Anatola Elementary in Van Nuys. Off-Campus school visits consisted of solar-telescope viewing, dry-ice comet making and interactive lessons about galaxies, stars and planets. The on-campus visit included the same activities, a brief department tour, and planetarium shows. Outreach events are initiated by requests from the teachers, through our webpage, and from our department staff directly. In May 2011 Astronomy Live! was awarded the Bruin Heroes Award in recognition of our volunteer efforts at UCLA and in the community. As this program develops it is the goal of Astronomy Live! to visit middle and high schools, hospitals, and local events to interact with the community to foster interest in astronomy and science in general.

On November 13, 2010 the second annual Exploring Your Universe event took place. This free public event included talks, demonstrations, exhibits, and hands-on activities from the Physics and Astronomy Department, Earth and Space Sciences, Atmospheric Sciences, the CNSI High School NanoScience Program, and the Center for Environmental Implications of Nanotechnology. This year there were about 1300 attendees, an increase from the ~1000 in its inaugural year. Astronomy Live! is currently planning Exploring Your Universe 2011 for November 12. For information on this event and other outreach opportunities **visit the website: http://www.astro.ucla.edu/~outreach/**

Free weekly planetarium shows are also provided Wednesday nights by the astronomy graduate students, and outreach activities can be coordinated along with the planetarium for larger groups of students. **Visit the planetarium website for more information: http://www.astro.ucla.edu/planetarium/**

## UCLA ALUMNI DAY May 21, 2011

Former students, new students, future students, all connecting at UCLA. Stories from previous alumni, plans of future alumni, stories about how much UCLA has changed since graduating in 1981. Memories of the campus traded by former students with current students - a bond that will last a lifetime. An amazing day!




Each spring UCLA alumni have a great day at their alma mater when the campus celebrates UCLA Alumni Day. Seminars and demonstrations were conducted by distinguished professors throughout campus. Students in the Department of Physics and Astronomy organized physics demonstrations, as well as solartelescope viewing and planetarium shows.

Above, students demonstrate the wonders of physics as is Chair, James Rosenzweig above right.

## Celebra la Ciencia Community Fair

As in the past nine years and with the support of the UCLA Plasma Science and Technology Institute, a booth at the "Celebra la Ciencia Community Fair" held at the end of the "Chavez Memorial March" on Sunday, March 27, presented physical principles to the public. The effort was organized by Dr. J. Manuel Urrutia and was assisted by Prof. Eric Hudson, research scientists Drs. Frank Tsung and Michail Tzoufras, Dr. Martin Simon, who is in charge of the Department's lecture demonstrations, Dr. Simon's assistant, Mr. Gueorgui Gueorgiev, as well as Mr. Henry Gonzalez, an undergraduate physics student and Hispanic Center of Excellence Mentor at UCLA's Center for Community College Partnerships.

## CAREER NIGHT 2011, Thursday, April 7, 2011

The department's annual Career Night on April 7, 2011 was a great success with students and panelist enjoying pizza, drinks and dessert, followed by interesting questions from the students and equally interesting and helpful answers from the panelists ( Thomas Meseroll, Kinkead Reiling, John Taborn, Laura Marchand, and Darius Gagne,). This event provided the students with a wonderful opportunity to talk with some of the department's alumni about the reality of finding jobs after graduation in a variety of career paths.

Panelists left to right: Thomas Meseroll, Kinkead Reiling, Laura Marchand and Darius Gagne

**If you want to participate in the annual Career Night event, please contact the chair's office at chair@physics.ucla.edu.**

## Research Experience for Undergraduates (REU program) 2011

The Physics & Astronomy department is hosting the 9th annual Research Experience for Undergraduates (REU program) during Summer 2011. Fourteen undergraduate students have come came from across the country to engage in real frontier level research with a UCLA faculty member for a period of 10 weeks. Each of the participants was matched with a faculty mentor according to the student's stated interests.The projects spanned the various fields represented in the department, such as plasma physics, biophysics, cosmic ray physics, astrophysics, accelerator physics. The students are being trained in the newest lab, computational and theoretical techniques to prepare them for the world of research. Over the last 9 years, the department has hosted a total of 120 students under this program.

## Taylor Barrella, UCLA Physics Major Undergraduate Wins Prestigious Barry Goldwater Scholarship

Congratulations to Taylor Barrella, UCLA physics major undergraduate, for winning the prestigious Barry Goldwater Scholarship. The program was established by Congress in 1986 to provide a continuing source of highly qualified scientists, mathematicians, and engineers by awarding scholarships to college students who intend to pursue careers in these fields. It is generally considered the most prestigious award in the U.S. conferred upon undergraduates studying the sciences.

2010-11 Award Recipients from left to right: John Bishoy Abraham, Rudnick-Abelmann Scholarship, Katherine E. Kaufman, Charles Geoffrey Hilton Award**,** Taylor Barrella 2010-2011 Winstein Award for excellence in independent work in Particle and/or Nuclear Physics

## AWARDS

**RUDNICK-ABELMANN SCHOLARSHIP**

John Bishoy Abraham
Midhat Farooq
Scott Michael Mills
Youna Park
Brian Robert Shevitsky

**WINSTEIN AWARD**

Taylor Barrella

**CHARLES GEOFFREY HILTON AWARD**

Katherine E. Kaufman

**E. LEE KINSEY PRIZE**

Natalie Mashian

GRADUATES 2010-2011

## Bachelor of Science in Physics

George Amir Asaad
Brian Jon Belleville
Yung-Chuan Chen
Robert Jack Cunningham
Juliana Christine Curtis
John Jeffrey Damasco
Paul Daniel Ekstrand
Edwardo Fernandez
Bryce Flores Flor
Zachary Brooke Hoyer
Brian L. Le
Byeong Y. Lee
Marta Luengo-Kovac
Jena Lea Meinecke
Patrick Namasondhi
Anh B. Nguyen
David Julien Nicholaeff
Stephen Matthew Nichols
Abhishek Suhas Pathak
Michael Simon Prager
Julio S. Rodriguez Jr.
Henry Huang Stoltenberg
Paul Michael Villaluz
Xuan Wei
Kendall Paige Woodruff
Mario Vincent Yeh
Chong H. Yi
Reza Zarinshenas

## Bachelor of Art in Physics

Anton Bobkov
Eben Gunadi
Wade Nicholas Rex
Andrew Toy

## Bachelor of Science in Astrophysics

Kristen Alicia Bennett
Rachel Cane
Brooke Erin Duitsman
Kristin Lesley Fitzmorris
Zachary Schuyler Green
Ding Bang Huang
Katherine E. Kaufman
Natalie Mashian
Sarah R. Nagy
Matthew Joseph Palomar
Barret William Schlegelmilch
Jeffrey Alan Spahn
Wilhelm Alexander Weidmann

## Bachelor of Science in Biophysics

Maia Lee Eng
Branden Louis Galvez
Kenneth Liao
Michael Zenkay Liu
Samuel Paxton Milechman
David James Rowland

**Roberto Peccei** addressed the graduates of the Physics and Astronomy Department at UCLA on June 11, 2011. Excerpts have been taken from Roberto Peccei's talk as follows:

Commencement is a special time for graduates and their parents, family and friends. Commencement is probably one of the happiest days that all of you will have in your life. So, enjoy it!

Thinking about what to say today, I decided it would be most useful if I spent some time reflecting on what kind of future you will face. A majority of you will continue to pursue a career in Physics or Astronomy, but many of you are already embarking on quite different paths. No matter what the next phase of your life- journey turns out to be, you are all very fortunate to have gotten a degree from the Department of Physics and Astronomy at UCLA.

*… if you were trained as a physicist or an astronomer you can do anything you put your mind to in life!*

I am certain that those of you who are now choosing a different path to pursue than being a professional physicist or astronomer will find equally exciting opportunities in whatever field you choose. The most useful piece of advice that I can give all of you is to simply pursue your passion. If you do so, you will do what excites you, and that will make you happy and this is most likely to make you successful.

It is unquestionable that our world is undergoing rapid change and that you will have to adapt to, and hopefully shape, some of the changes that will occur in the next half century. Four areas which are particularly critical to our future: Ethics; Environment; Energy; and Economics.

Of the four Es, Ethics stands apart as it is the foundation of our value system.

## Doctor of Philosophy Astronomy

David Rodriguez
*Advisor: Ben Zuckerman*

## Doctor of Philosophy Physics

Jeremy Althouse
*Advisor: Terry Tomboulis*

David Auerbach
*Advisor: Troy Carter*

Ethan Brown
*Advisor: Katsushi Arisaka*

Antoine Calvez
*Advisor: Alex Kusenko*

Kwun Hung Cheung
*Advisor: Hong-Wen Jiang*

Antoine Calvez
*Advisor: Alex Kusenko*

Warren Essey
*Advisor: Alex Kusenko*

Lea Fredrickson
*Advisor: Dolores Bozovic*

John Goetz
*Advisor: Bernard Nefkens*

Yu Guo
*Advisor: Eric D'Hoker*

Erik Hemsing
*Advisor: James Rosenzweig*

Shahzad Khalid
*Advisor: Seth Putterman*

Beth Klein
*Advisor: Michael Jura*

Nathan Kugland
*Advisor: Christoph Niemann*

Chi Wai Lam
*Advisor: Katsushi Arisaka*

Jonathan Landy
*Advisor: Joseph Rudnick*

Matthew Mecklenburg
*Advisor: B. Chris Regan*

Lei Shao
*Advisor: David Cline*

Scott Singer
*Advisor: B. Chris Regan*

C. Elliott Strimbu
*Advisor: Dolores Bozovic*

Artin Teymourian
*Advisor: Katsushi Arisaka*

Jordan Tucker
*Advisor: Robert Cousins*

Yong Wang
*Advisor: Giovanni Zocchi*

Andrew Yu-Jen Wang
*Advisor: Giovanni Zocchi*

Clement Wong
*Advisor: Yaroslav Tserkovnyak*

Jeffrey Wright
*Advisor: Stuart Brown*

The second E, Environment. I believe the global threats facing mankind are most clearly perceived in connection with the environment. Academia has been one of the real agents of change on environmental issues. The science and policy ideas needed for the success of these efforts are, again, mostly being pursued by small groups of academics scattered across the globe, but linked intellectually. Many of them have a degree in physics, as you now also have. So, perhaps, this may be an interesting path that some of you will follow in the future.

Energy, the third big E. In essentially all universities, myriads of faculty members are very actively and broadly engaged in energy research. But science and engineering are not all that is required to move the world along a sustainable energy path. One needs also to understand what policy measures need to be implemented (fiscal and economic incentives, regulatory legislation, etc) to make sustainability an integral component of society across the globe. For some of you that may be so inclined, there are opportunities and challenges waiting for you.

The last of the 4Es: Economics. This is a hot topic in view of the global economic meltdown. Unless we can restructure the global economy so that it truly leads to economic development which is sustainable we will undermine our delicate environment on earth and irreversibly deplete its resources, leading to catastrophic consequences. This offers opportunities to others – perhaps even for some of you! - to think through how to reshape the present economic system into one where natural capital is given a real economic value.

*"the issue now is … whether the environment is part of the economy or the economy is part of the environment".*
*Eco-Economy: Building an Economy for the Earth. Lester Brown (W. W. Norton & Company Inc., New York, 2001)*

… You are standing at the threshold of a world full of opportunities and challenges. The Department and UCLA have prepared you well to face this world. You all have the innate ability to succeed and make a difference. So, go forward with confidence and makes us all proud! I wish you all the best of luck for the future.

UCLA Department of Physics and Astronomy
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Los Angeles California 90095-1547