UCLA

Department of Physics & Astronomy

fusion energy

"What we are all trying to do is harness the processes that go on in the interior of the Sun, but under controlled conditions in a laboratory."

Annual Report 2008-2009

UCLA Physics and Astronomy Department
2008-2009
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Department of Physics & Astronomy

2008-2009 annual report

UNIVERSITY OF CALIFORNIA, LOS ANGELES

Message from the Chair:

Ferdinand Coroniti, Chair

The Department starts academic year 2009-10 with the normal hopes and aspirations tempered by the State's ongoing financial difficulties. Basically, the Department survived last year's cuts in a reasonably healthy condition, but the future remains quite uncertain.

First, the positive developments. Professor Edward Wright, holder of the David S. Saxon Presidential Chair in Physics, was joined by two new chaired professors. Professor Sudip Chakravarty was appointed to the David S. Saxon Presidential Term Chair in Physics in recognition of his outstanding contributions to theoretical condensed matter physics. Professor Andrea Ghez was appointed to the Lauren B. Leichtman and Arthur E. Levine Chair in Astrophysics in recognition of her path-breaking investigation of the Galactic Center and its supermassive black hole. Both of last year's searches succeeded in the recruitment of excellent young faculty members. Assistant Professor Michael Fitzgerald, Ph.D., in astronomy from UC Berkeley and currently a postdoc at LLNL, joins Professors J. Larkin and I. McLean in the Infrared Laboratory; he specializes in adaptive optics infrared instrumentation and debris disks in exosolar planetary systems. Associate Professor Mayank Mehta, Ph.D., from the Indian Institute of Science Bangalore in elementary particle physics and currently an assistant professor at Brown University, has a split appointment with the Department of Neurology in the UCLA medical school and is also a member of the California Nano-Systems Institute (CNSI). Professor Mehta specializes in neuroscience and is world-renowned for his experimental and theoretical investigations of sequence learning in the brain.

In 2008-09, the Department awarded a record number of 34 Ph.D.s in physics and a near record number of 7 Ph.D.s in astronomy. The total number of undergraduate physics majors climbed to an all-time high of 220, including 37 in the new biophysics major. The astrophysics major had 52 students. A total of 68 undergraduates received bachelors degrees, tying the record of the year before.

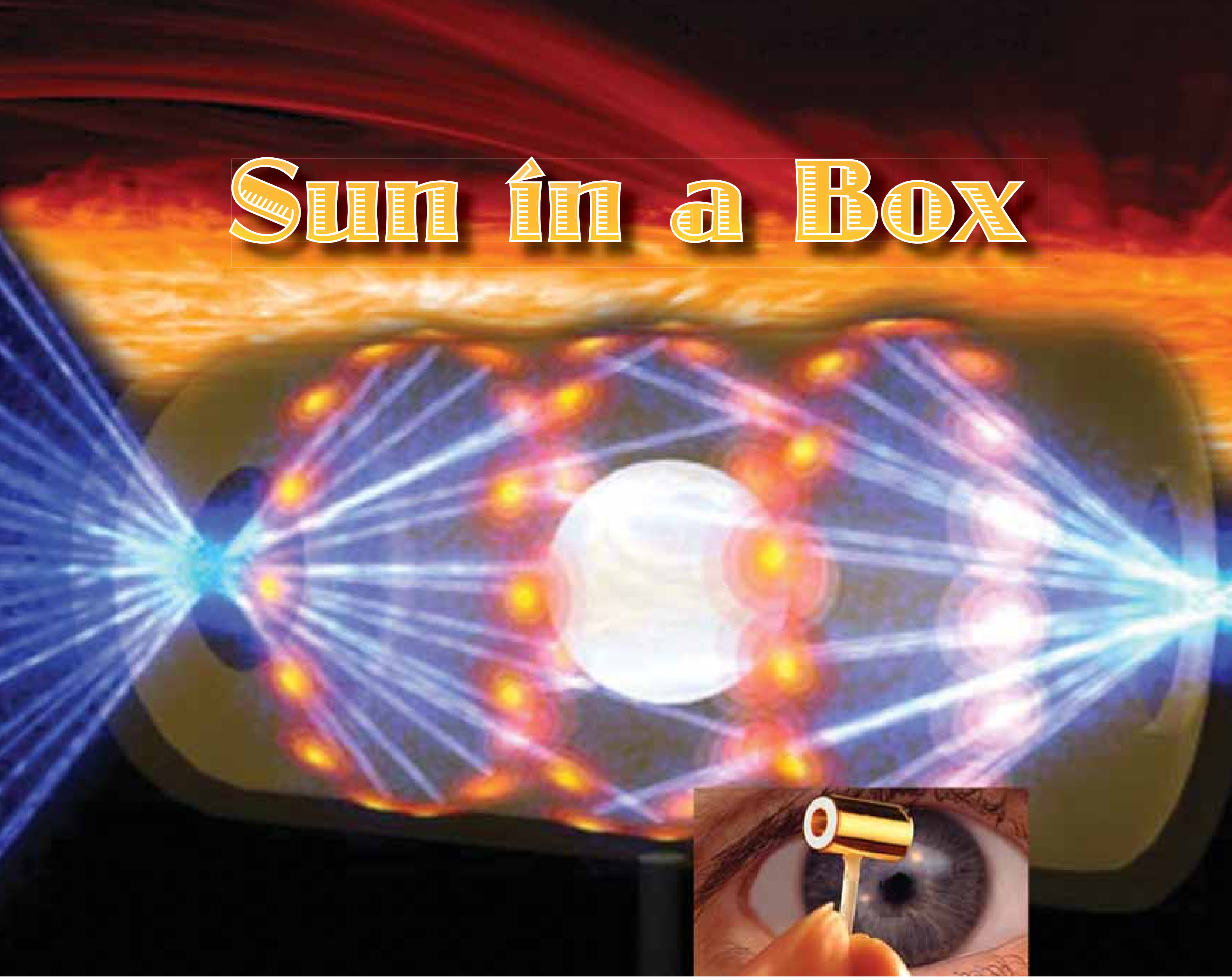
The research activities of the Department are presented later in this report, so only a few highlights will be mentioned here. The Wide-field Infrared Survey Explorer (WISE), a JPL project with Professor E. Wright as the PI, is on schedule for an early December launch from Vandenberg Air Force Base ... Professor I. McLean will deliver the Multi-Object Spectrometer For Infrared Exploration (MOSFIRE) to the Keck Observatory in June, 2010 ... Professor R. Ong was elected the spokesperson of the VERITAS Observatory ... Professor D. Saltzberg successfully completed the ANITA II campaign, a balloon-borne experiment launched in Antarctica to measure high energy cosmic neutrinos ... Professors K. Arisaka, D. Cline, R. Cousins, J. Hauser, and R. Wallny are poised for the (second) start of CERN's Large Hadron Collider; Professor Cousins will step down in January as the deputy spokesperson for Compact Muon Solenoid (CMS) experiment ... Professor T. Carter and his Ph.D. student Dr. A. White made the first measurements of the electron temperature fluctuations in the General Atomics' DIII-D tokamak in San Diego; for this work, Dr. White was awarded the Rosenbluth Prize by the APS for the best Ph.D. thesis in plasma physics (see the feature article in this report) ... Professor B. C. Regan has created the world's smallest light bulb – a carbon nanotube lamp – to explore the properties of thermal radiation at nanometer scales ... Professor E. Hudson has turned an empty room into a state-of-the-art quantum atomic optical physics laboratory and is investigating whether molecular ions can be used as qubits in a quantum computer ... Dr. H. Wang and Professors K. Arisaka and D. Cline have created a world-class dark matter laboratory and are developing plans for liquid argon and xenon detectors of 1-10 ton scale ... Professor J. Miao has developed novel x-ray image reconstruction techniques that will revolutionize the measurements made by the new Linac Coherent Light Source (LCLS) at Stanford ... Professor K. Arisaka has completed a prototype twin-photon microscope that is currently being tested in the medical school.

The less positive developments concern the budget situation. The Department's share of the 20% cut to the state-supported part of the University of California's budget amounted to 5% of our total budget or about 17% of "cut-able (non-faculty) budget. Last year's cuts – all of the temporary teaching faculty, 3.67 full TA positions, and half the Reader funds – are now permanent. The Department has reduced the curriculum by 12 courses (the Honors versions of Physics 1ABC and 6ABC, sections of Physics 6 and 10 and Astronomy 6, many upper division electives, and most graduate seminars); an estimated 730 "seats" (enrolled student places) were lost. In addition, five senior staff members decided to retire rather than accept significantly altered work responsibilities, a consequence of planned layoffs; these positions are now lost. The Department also realized that a permanent $440k structural deficit had developed in the graduate student recruitment program. The Department has been competing successfully against the top U.S. physics and astronomy departments for the best graduate applicants by offering attractive (read high) financial recruitment packages; roughly 25-30% of our top applicants now decide to accept admission. The commitments to these outstanding students, and the reductions in graduate support provided by the Graduate Division and the Dean have resulted in the above deficit, which will almost certainly grow over the next few years. The Department will cover the deficit by a combination of earnings from Summer Sessions and Indirect Cost Recovery (overhead return) on contracts and grants, and will continue to admit an entering graduate class of about 20-22 in physics and 5-6 in astronomy. However, the finances of graduate recruitment will remain precarious as the expenses to compete continue to rise and state support continues to diminish.

As always, the Department deeply appreciates the interest and support of its friends and alumni. Your past generosity has significantly contributed to the enrichment of the Department's academic program. Thanks to your support, we were able to establish a new undergraduate computing laboratory and will offer our majors a new course in computational analysis. Hopefully, despite the budget problems, together we can continue to build a truly excellent physics and astronomy program at UCLA.

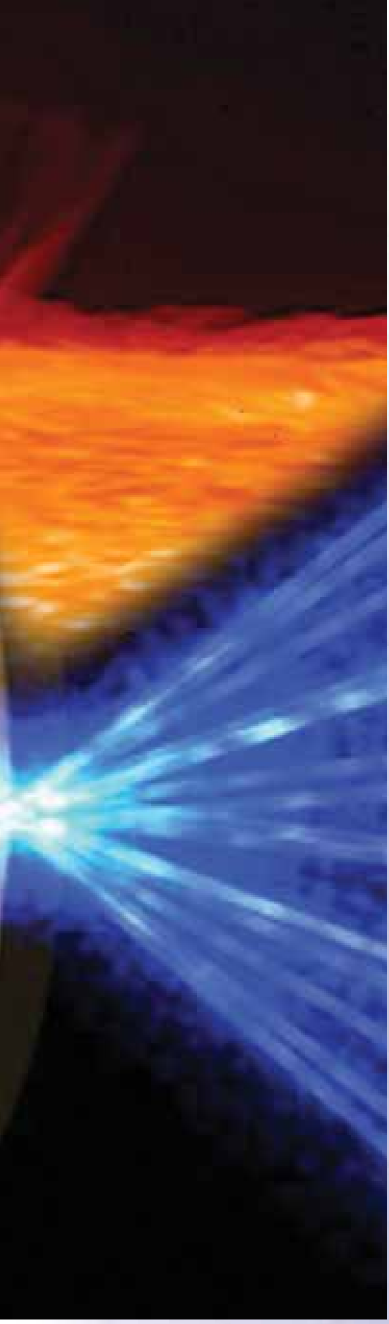
Ian McLean, Vice-Chair

Sun in a Box



Plasma Physics and the Goal of Fusion Energy

Most of the visible Universe is in the plasma state—a hot gas in which the atoms have been stripped (ionized) of their electrons. Although plasmas are now common in our modern technological civilization—fluorescent lights, TV screens, computer chips—their most important contribution is likely to come in the future. Plasmas promise a virtually inexhaustible source of energy via the fusion of the light isotopes of hydrogen into helium. The Sun, of course, has been routinely fusing hydrogen in its core for the last 4.5 billion years. Professor George Morales, the director of the UCLA Plasma Science and Technology Institute, sums up the fusion problem on Earth: "The trick is to create a sun and keep it in a box."



The basic concepts involved in confining hot, dense plasma in a magnetic field (or box) until fusion reactions have time to occur were developed in the 1950s and early 1960s. However, in the laboratory, confining hot plasma is like herding cats—the gas delights in leaking out of the box. In the mid-1960s, with the advent of high-powered lasers, a second route to fusion was conceived—inertial confinement, which involves hitting a small pellet of frozen hydrogen so hard and fast that the plasma is confined by its own inertia and is compressed and heated to fusion temperatures before it can escape from the box. For the past 40 to 50 years, both magnetic fusion and inertial confinement fusion programs have been pursued by the U.S. Department of Energy—and its counterparts in industrialized nations around the world—with the overarching, long-term goal of achieving controlled fusion as the ultimate energy source for human activity on Earth.

The UCLA Department of Physics and Astronomy's plasma physicists aim to fulfill the promise of fusion in many ways from theoretically understanding the fundamental physics of plasma phenomenae to experimentally investigating plasma processes that are likely to occur in fusion devices to numerically simulating plasma dynamics on the world's largest computers. Vital to their progress are collaborations with other plasma research efforts at UCLA in the School of Engineering, the Institute of Geophysics and Planetary Physics, and the Department of Earth and Space Sciences. Outside UCLA, scientific partnerships range from top universities to major national and international projects such as Lawrence Livermore National Laboratory's National Ignition Facility (NIF) and the International Thermonuclear Experimental Reactor (ITER). This article highlights the magnetic and inertial confinement fusion efforts of Department plasma researchers in concert with their prestigious colleagues.

Magnetic Fusion

Building on the heritage of many tokamaks, including the current General Atomics DIII-D National Fusion facility in San Diego, the Madison Symmetric Torus in Wisconsin, and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory, the ITER will be the largest magnetic confinement device ever attempted. Being huge in scale, ITER will contain low-frequency, long wavelength modes that can grow to destroy the confinement of the plasma.

Until the creation of the Large Plasma Device (LAPD) by Professor Walter Gekelman, these modes could not be thoroughly investigated in the laboratory. Considering that ITER's very hot plasma will be extremely difficult to measure either in situ or remotely, UCLA's Plasma Diagnostics Group (PDG), founded by Dr. Tony Peebles, is developing novel measurement devices and techniques and testing them on the current U.S. tokamak facilities. The longevity of ITER's plasma will depend on whether or not plasma turbulence, on large and small scales, rapidly diffuses thermal energy to the walls of the device, so Professor Troy Carter is investigating the nonlinear effects of plasma turbulence in collaboration with the LAPD and PDG efforts.

Large Plasma Device and Beyond

Available to qualified scientists at UCLA and national and international institutions, the Large Plasma Device (LAPD) in the Department's world-class Basic Plasma Science Facility is a key resource for fusion-related research. Currently, it is the largest device in existence for basic experiments in plasma under controlled conditions. Operations began in 2001 under the direction of Professor Walter Gekelman with a grant from the Department of Energy (DOE) and the National Science Foundation (NSF); the facility is currently in its second round of funding.

The primary function of the LAPD is to make research quality plasma in which a variety of experiments related to space plasma physics, fusion and astrophysics can be performed. The first step in making plasma is to pump the air out of the large vacuum chamber (1 meter in diameter and 22 meters long) to avoid contamination. Then a tiny amount of gas (usually

If we are to be an advanced civilization,
we must conquer fusion—it's fusion or bust.

helium) is bled back into the chamber, after which researchers pulse on an electron beam. The beam ionizes the helium and fills the chamber with plasma in a thousandth of a second. The plasma is shut off and then the process is repeated at 1 Hz, day and night. Researchers introduce whatever they need for their experiments to disturb the plasma and trigger the phenomena they wish to study. They measure the magnetic field, plasma density, temperature, flows, and other quantities with specialized probes, which are moved, millimeter by millimeter, throughout the plasma. The measurements are digitized and stored for analysis. The LAPD is the fifth plasma device that Walter has developed at UCLA, each progressively larger and more technologically sophisticated. Says Walter, “We made the device very flexible, so without a lot of difficulty, we can change from one kind of experiment to another in about a day.”

As a user facility, the LAPD operates around the clock—the maintenance costs are covered by an NSF/ DOE partnership grant. Fifty percent of its operations are committed to non-UCLA faculty who arrive from universities around the country and the world. This influx incidentally leads to cooperative projects with UCLA researchers, an enrichment that comes as an added benefit to Department physicists. Says Walter, “The responsibility for managing and maintaining the facility is UCLA’s, and this requires the skills of Department faculty, technicians and students. Also, we are constantly adding improvements. For this level of investment, we have exclusive use of the device the other 50 percent of the time.” Walter’s group is currently studying the interaction of dense plasmas (produced by lasers) with a background plasma and the interaction of hot ions and electrons with different types of plasma waves.

In the planning stages and also under the direction of Walter is a new device—the Enormous Toroidal Plasma Device (ETPD). Walter and his group are converting a large tokamak machine into something very different. He suggests, “It will make an unusual plasma that is suited for astrophysics research. The plasma will have enormous pressure and be very long—120 meters. Plasma with the properties we are planning does not yet exist at any other facility.” He concludes, “It will likely become a user facility as well.” The plasma in the ETPD will be pulsed and diagnostics similar to the LAPD will be used, but there are differences: The LAPD has a very strong magnetic field, but the plasma is not very dense, whereas the ETPD will be exactly opposite with a very dense, hot plasma, but a much weaker magnetic field—characteristics similar to conditions in space (such as solar wind).

The Sun ... has been routinely fusing hydrogen in its core for the last 4.5 billion years.

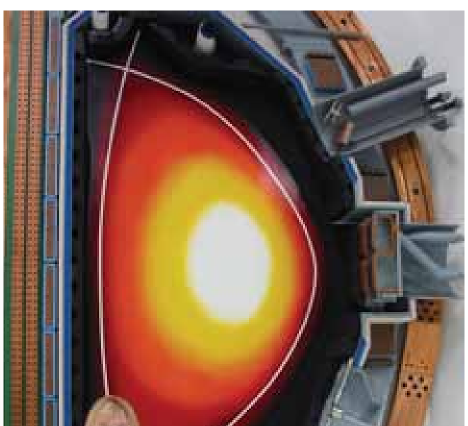
Plasma Diagnostics Group

The UCLA Plasma Diagnostics Group (PDG), under the direction of Senior Research Scientists Tony Peebles, David Brower and Terry Rhodes, develops non-perturbing state-of-the-art millimeter-wave diagnostics to probe hot fusion plasmas in order to better understand and control them. Due to the nature of the work, the PDG is highly collaborative, interacting with fusion plasma devices around the country.

Diagnostic systems are initially developed in the Plasma Diagnostics Laboratory at UCLA and then transferred to off-site fusion facilities. Following installation, PDG staff remain at the facility and participate in the scientific effort. The quality of their work is outstanding and has been recognized by the plasma community.

Says Dr. Tony Peebles, "The DIII-D National Fusion Facility in San Diego is our largest project to date." The diagnostic systems installed by UCLA researchers on DIII-D are playing a major role in improving our understanding of fusion plasma science with particular emphasis on the physics responsible for the anomalous loss of heat and particles caused by turbulence.

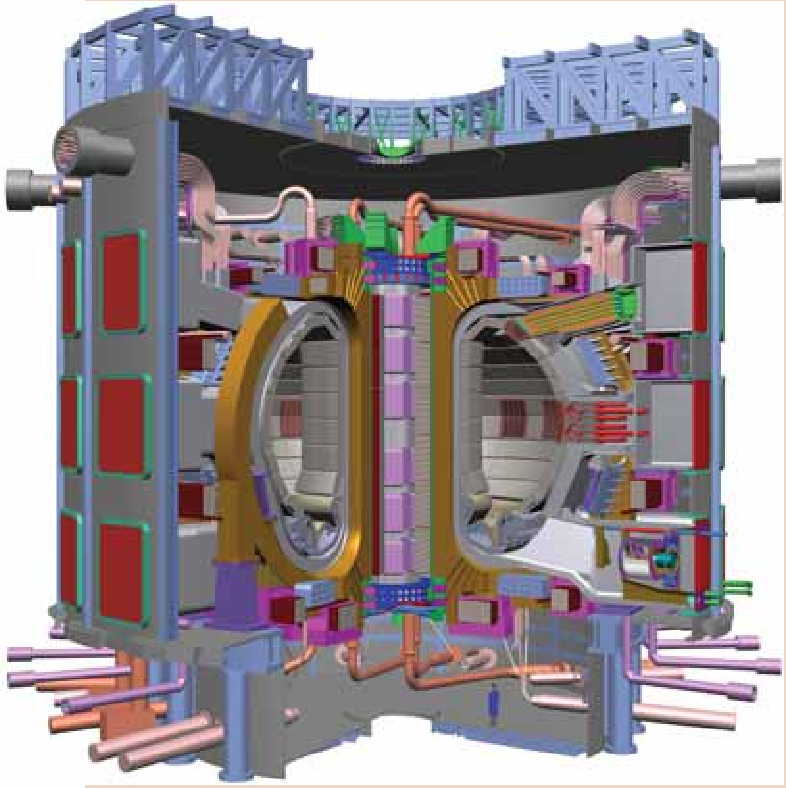
The PDG is also an active team member of the National Spherical Torus Experiment (NSTX). The focus of this research is two-fold. First, UCLA is involved in improving our understanding of the interplay between fast-ion driven instabilities and fast-ion confinement, which is particularly important for fusion plasmas where 3.5 MeV alpha particles are created in the hot core. Second, since spherical tori have a rather unique magnetic configuration and operate at high plasma beta, investigating turbulence and transport in such plasmas can improve our overall understanding of other fusion configurations.



Dr. Anne White in front of full size mock-up of DIII-D tokamak in San Diego.

Finally, led by Dr. David Brower, the PDG is consulting with the University of Wisconsin, Madison, on the Madison Symmetric Torus (MST), the world's leading reversed field pinch fusion plasma facility; and on the Helically Symmetric Experiment (HSX), a new stellarator concept for magnetic confinement. The focus of these efforts is to understand the role of magnetic and current fluctuations in transport and stability.

International Thermonuclear Experimental Reactor (ITER)



The world's largest tokamak is intended to demonstrate a burning plasma and test the feasibility of fusion as a future energy source.

The result of a world-wide collaboration established in 2007, the International Thermonuclear Experimental Reactor (ITER) is the most ambitious plasma science endeavor to date. Located on 400+ acres in Southern France, the tokamak will occupy a 19-story building and weigh 23,000 tons. It has been designed with superconducting magnets to produce 500 MW of output power. (The current record for released fusion power is 16 MW.)

The promise of ITER is to create a threshold that will support a self-sustaining plasma— comparable in temperature to the Sun—and confine it in a space that can safely produce energy. A plasma that can continuously self heat at this level (150 million degrees centigrade) has not yet been accomplished on Earth but is absolutely necessary to forge an alternate energy source.

The ITER collaboration includes the People's Republic of China, the European Atomic Energy Community (via EURATOM), the Republic of India, Japan, the Republic of Korea, the Russian Federation, and the United States of America (the U.S.A. is a 10 percent partner). The seven members will bear the cost of the facility (more than $10 billion) through its 10-year construction period, which was initiated last year, and its (estimated) 20-year operational period; the members will exclusively share its use.

The conceptual design for the project began 20 years ago, undergoing progressive refinement until 2001 when the members unanimously approved the agreement. UCLA's Professor René Pellat, in his position as Haut-Commissaire à l'Energie Atomique, was influential in forming ITER. UCLA physicists will continue to make scientific contributions to the project.

Turbulence, Transport, and Nonlinear Processes

Transport of heat, particles, and momentum is fundamentally important in magnetized plasmas. Working with both the Large Plasma Device and the Plasma Diagnostics Group, Professor Troy Carter is studying the effects of turbulence and other nonlinear processes on plasma transport.

Troy's experiments on the LAPD concentrate on pressure-gradient-driven instabilities and how they lead to particle and heat transport across a confining magnetic field. This research has direct relevance to the outer region of fusion plasmas, which have density and temperatures not too different from those found in the LAPD. In particular, Troy is exploring the formation of "blobs," which are filamentary plasma structures in turbulence driven by pressure gradients. Convective transport of these structures explains a large fraction of particle losses in devices like tokamaks. Another of Troy's LAPD projects concerns an astrophysical toroidal device—an accretion disk. In radiatively inefficient disks, like the one around the supermassive black hole at the center of our own galaxy, collisional processes are insufficient to cause angular momentum transport and heating, and plasma turbulence must be invoked to explain the observations. Says Troy, "If we can understand nonlinear processes and heating associated with Alfven waves in a simple laboratory plasma, we can directly test theories and nonlinear simulation that can then be applied to explain astrophysical plasmas."

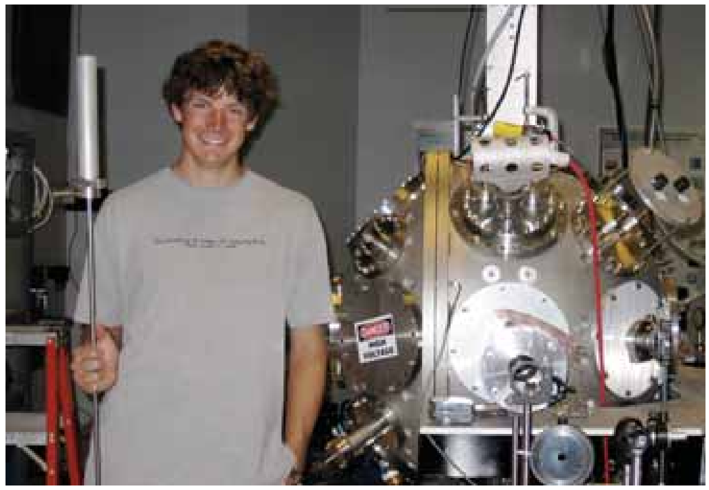
Troy's work on high temperature tokamaks is done in collaboration with the Plasma Diagnostic Group. Troy and his graduate students take advantage of the extensive suite of microwave diagnostics fielded by this group to study instabilities and turbulence in tokamaks. Troy explains, "We're trying to provide a fundamental understanding of plasma, which is vital to controlling transport and improving confinement in fusion devices. This kind of research will help ensure the success of ITER."

Inertial Confinement Fusion

When laser beams strike a frozen deuterium-tritium pellet, their tremendous radiation pressure ionizes the surface layer and drives a strong imploding shock into the pellet's core. The shock compresses and heats the core to densities and temperatures at which fusion reactions commence; in effect, the pellet becomes a small hydrogen nuclear explosion device. For success, two conditions must be met: The implosion must be highly spherically symmetric to obtain maximal compression; and plasma instabilities that develop in the surface layer must not become so strong that the laser radiation is back scattered and thus prevented from reaching the core. Both goals are very challenging and have engendered extensive scientific effort by UCLA Professors Christoph Neimann and Warren B. Mori and their colleagues. Christoph conducts research in laser fusion that will eventually culminate in NIF experiments; Warren models experiments in three dimensions to create computer simulations of high energy density plasmas.

Professor Christoph Niemann is preparing to lead UCLA's laser fusion activities at the National Ignition Facility (NIF) through a highly coveted appointment at the Lawrence Livermore National Laboratory (LLNL). Following four years of post-doctoral study there in plasma physics,

The LLNL National Ignition Facility



Lucas Morton, an REU student using the mini NIF at UCLA

Christoph was recruited in 2006 to joint appointments in UCLA's Department of Physics & Astronomy and Electrical Engineering Department. He explains, "My appointment at the Lawrence Livermore Lab creates a link to NIF for UCLA, establishing a relationship that is intrinsically difficult for universities because of the classified work going on in the lab." His position will be a conduit for other UCLA scientists as well—including graduate students—incidentally providing a unique opportunity to be at the forefront of fusion history.

Moving in a direction that will lead to NIF experiments, Christoph and other UCLA researchers conduct studies with mid-scale lasers at high-powered facilities around the country, including LLNL. These lasers are very impressive and accessible—faculty and students can conduct tens of shots per day for many weeks during the year.

In addition, the Department operates a mini NIF laser on campus, which provides hands-on training and complements the research conducted on the world's most powerful lasers at the national labs. The device is small enough that researchers can conduct basic experiments with it, yet powerful enough to be relevant for laser fusion. Says Christoph, "At UCLA we operate the only high-energy glass laser in the country that is designed, built, and operated by students."

The short duration and extremely high energy density of the plasma created in NIF presents physicists with an extraordinary challenge in their attempts to interpret experimental results.

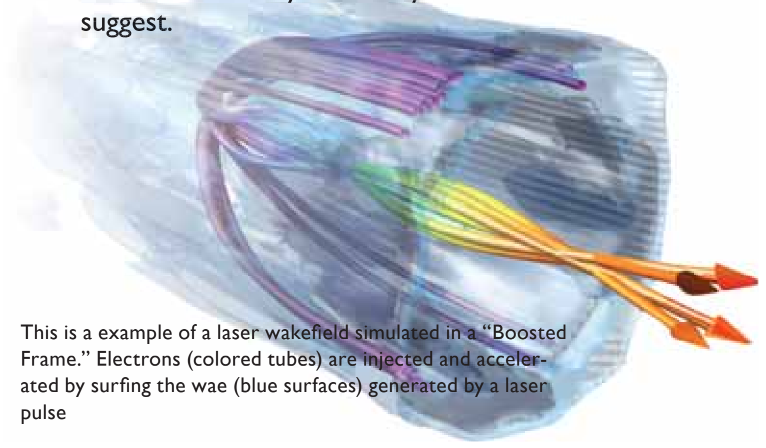
Computer Simulations of High Energy Density Plasmas

Professor Warren B. Mori, a physicist in theoretical plasma with joint appointments in physics and the Henry Samueli School of Engineering and Applied Science, and his team lead the world in particle and cell simulations of high energy density plasma phenomena.

Mentored by the late John Dawson, the father of computer-simulated plasma models, Warren now partners with Professor Chan Joshi in the UCLA Electrical Engineering Department and with faculty all over the country who are working with lasers and particle beams. Experiments are modeled and then sent from his desktop computer to some of the largest computers in the world, including some in the Lawrence Livermore and Oakridge national laboratories.

At NIF, Warren and his team are investigating the processes inherent in confining the plasma as the pellet is compressed to a thousand times the density of a solid. The pellet's implosion must be highly symmetric in order to maximize the potential fusion reactions occurring in its core. Warren is using computer simulations to determine just how uniform the NIF compression must be. On a more basic and general level, the team is studying the various ways lasers interact with high energy density plasma.

UCLA physicists are advancing plasma research in a variety of ways in order to deepen our understanding of this state of matter. On a practical level, plasma fusion will likely fuel our future; as a byproduct, the manufacturing of plasma will create products and services that can fulfill our dreams in ways that only science fiction has dared to suggest.



This is a example of a laser wakefield simulated in a "Boosted Frame." Electrons (colored tubes) are injected and accelerated by surfing the wae (blue surfaces) generated by a laser pulse

Lawrence Livermore National Laboratory's National Ignition Facility

The world's largest laser promotes fusion energy through plasma research and supports national security through weapons research.

Located at the Lawrence Livermore National Laboratory (LLNL) in Northern California, the National Ignition Facility (NIF) contains 192 giant laser beams; spans three football fields; and occupies three interconnecting buildings, including one 10-story structure housing the laser itself. It is the culmination of unprecedented collaboration between U.S. scientists in government, industry and academia over the course of 50 years.

When NIF is fully operational, it will be the largest laser in the world, creating in a laboratory, conditions similar to those inside the Sun. These conditions will be achieved by bombarding tiny BB-sized balls of fusion fuel composed of deuterium and tritium with all 192 lasers until they explode, creating the hottest plasmas on Earth.

Following NIF's dedication in May of 2009, LLNL scientists immediately began primary ignition experiments with a subset of NIF's 192 laser beams. After the ignition campaign, NIF will make its lasers available to approved academic institutions, including UCLA, 15 percent of the time. The other 85 percent will be dedicated to classified research by LLNL personnel.

UCLA's "NIF professor," Christoph Niemann, anticipates that successful ignition experiments will create a landmark year for plasma physics, enhancing the perception of fusion energy by both the public and the scientific community.

Lasers aimed at a target inside the NIF facility. The image at the left is showing the size of the target of the 192 laser beams.

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Woo, Mr. Robert
Woods, Dr. Thomas J.
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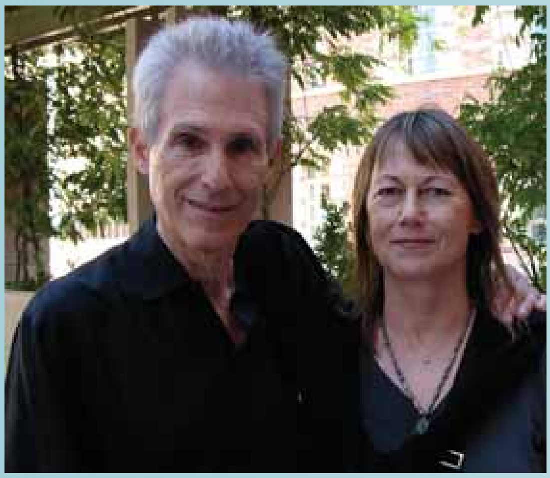
The Michael and Gretchen Kriss Teaching Assistant Awards
Kriss, Dr. and Mrs. Michael

Saxon-Kriss Graduate Student Emergency Fund
Kriss, Dr. Michael

"No act of kindness, no matter how small, is ever wasted."

Aesop (620 BC - 560 BC)

Astrid and Howard Preston



Howard and Astrid Preston's impressive and loyal support to UCLA continues with another generous donation to the Astrophysics Graduate Colloquium. Through their commitment and latest gift, this prominent series, held every Wednesday afternoon during the academic session, presents topics with such titles as "Black Holes of All Masses: New Results and Fundamental Correlations" and "Portraits of Distant Worlds: Characterizing the Atmospheres of Extra Solar Planets." These presentations bring to the UCLA campus such outstanding research scientists as Karl Gebhart (University of Texas) and Heather Knutson (Harvard University), to name just a few. Support from Howard and Astrid Preston for the colloquium not only enriches the education of our astrophysics' graduate students but the scientific community as a whole .

Howard received his B.S. and Ph.D. degrees in physics from UCLA. Astrid was awarded her B.A. in art. Numerous museums have exhibited her work, including UCLA's Hammer Museum. Howard is the president of Preston Cinema Systems and also serves on the Physics Advisory Council.

Along with their loyal commitment to the colloquium, the Prestons funded the Preston Reading Room in the Physics and Astronomy Building. Thank you.

John Wagner

The Ahmanson Foundation's gift, through the generosity of John Wagner, a member of the Ahmanson board, supports the maintenance of the physics and astronomy undergraduate labs. John earned his B.S. and M.S. at UCLA.

Traveling back in time, he reflects on the quality years spent on campus: " ... I was an undergraduate and graduate student at UCLA from 1976 to 1984. I supported myself and paid for tuition with the money I made at Santa Monica Hospital ER. I felt the education I received was superb. I had classes taught by Nobel Prize laureates. Rarely did an upper division class have more than 15 students; and I had unfettered access to the faculty. It was an extraordinary experience.

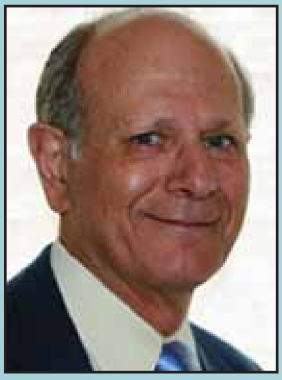
Sadly, my talent in physics did not match my enthusiasm, and I left graduate school to work on Wall Street, starting a hedge fund in 1990. Today we manage $3 billion and employ 30 people. I am married and have two boys. This fall, one is applying to UCLA."

Best wishes and luck to you, John. Your personal story enriches the archives of the Department of Physics and Astronomy. Thank you.

Michael Kriss

Another generous donation from Michael Kriss will be directed to the Department's teaching assistants. His past efforts have enabled the Department to make much-needed upgrades while pursuing the challenging mission of offering the finest education in the world.

Michael received his Ph.D. in physics from UCLA in 1969 and subsequently joined Eastman Kodak Research Laboratories. In 1982, he became laboratory head of the Image Processing Laboratory which helped lay the foundations for Kodak's entrance into the digital age. Upon retirement from Kodak, he joined the University of Rochester in 1993 where he was the executive director of the Center for Electronic Imaging Systems and taught in the Department of Computer and Electrical Engineering.



Michael's active career has carried him far and wide to such countries as China and Japan. In Japan, he worked with a team of managers to establish a Kodak research facility near Tokyo and was a visiting professor at Chiba University. He returned to the West Coast in 1999 as the manager of the Color Imaging Group at Sharp Laboratories of America until his retirement in 2004.

He is currently a Fellow of IS&T and the 1999 recipient of the Davies Medal of the Royal Photographic Society. Among his many pursuits, he teaches courses on digital imaging technology as an adjunct professor at Portland State University.

As an ongoing donor for many years, Dr. Kriss' gifts are matched only by the Department's continuous appreciation. Thank you.

Honoring Lauren B. Leichtman and Arthur E. Levine

Andrea Ghez with Lauren Leichtman and Arthur Levine

One night in late September, excitement flooded the 3rd floor patio of the Physics and Astronomy Building as guests arrived to honor Lauren B. Leichtman and Arthur E. Levine and celebrate Professor Andrea Ghez's appointment to the Leichtman & Levine Astrophysics Endowed Chair.

The Department of Physics and Astronomy and Dean Joseph Rudnick hosted the gala dinner and were joined by UCLA Chancellor Gene Block, Vice-Chancellor Roberto Peccei, and Department Chair Ferdinand Coroniti. The star-studded sky and beautiful weather created the ideal and appropriate setting for delicious food, jovial conversation and well-deserved accolades for our honorees.

Throughout the evening, speakers and guests showered well-deserved bon mots on these loyal and generous donors and on Professor Ghez, who accepted her appointment in her usual gracious and humble manner. She frequently expresses her extreme gratitude— in her own words: "Arthur and Lauren's unwavering support has afforded me the opportunity to do so much more than I could have, otherwise. This latest endowment just underlines their deep commitment to our research in a field that is highly competitive …"

The Department joins Andrea in saying "thank you."

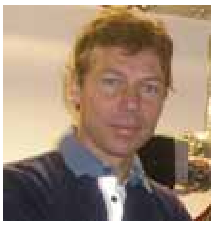
Lauren Leichtman and Arthur Levine being congratulated by Dean Rudnick

Arthur Levine, Lauren Leichtman, Andrea Ghez and Chancellor Gene Block

Howard Preston, Vice Chancellor Peccei and Robert Kaplan

focus on excellence — recognition of our faculty

Yaroslav Tserkovnyak received a National Science Foundation (NSF) Faculty Early Career Development Award of $585,000 for five years. Tserkovnyak's interests lie broadly in quantum transport and non-equilibrium phenomena in nanostructures. The NSF CAREER Program supports junior faculty within the context of their overall career development. It combines in a single program the support of research and education of the highest quality.



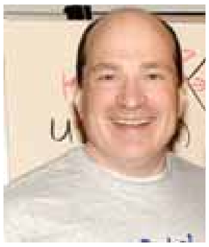
Pietro Musumeci received a 2009 Department of Energy (DOE) Outstanding Junior Investigator Award. The purpose of this program is to support the development of individual research programs by outstanding scientists early in their careers. Awards made under this program will help to maintain the vitality of high energy physics research and assure continued excellence in the teaching of physics.

Alexander Kusenko was elected as a 2009 Fellow of the American Physical Society at its meeting in November 2008. Kusenko was elected for "original and seminal contributions to particle physics, astrophysics, and cosmology, as the inventor of supersymmetric Q-balls, proposer of mechanisms for neutrino-driven pulsar recoil, proponent of sterile neutrinos as dark matter, and valued contributor to theories of baryogenesis and ultrahigh-energy cosmic rays."

Thomas Mason was elected as a 2008 Fellow of the American Physical Society. Tom was nominated by the Divison of Condensed Matter Physics for "pioneering the approach of microrheology of complex fluids based on the theral diffusion of probe colloids."

Eric Becklin was elected to the American Academy of Arts and Sciences this year in recognition of "preeminent contributions to his discipline and to society at large."

Sudip Chakravarty was awarded the American Chapter of the Indian Physics Association (ACIPA) Distinguished Scholar Prize (awarded jointly with Chandra M. Varma, UC Riverside) for wide-ranging contributions to condensed matter physics, in particular to strongly correlated electron systems. The *Physical Review and Physical Letters* 2009 has chosen Chakravarty as an outstanding referee. He has also been awarded the David S. Saxon Presidential Term Chair of Physics, 2009.



David Saltzberg was elected to a three-year term on the Executive Committee of the American Physical Society's Division of Particles and Fields.

Infrared Laboratory Group: Ian McLean and James Larkin

During the year 2008-2009, two major instrumentation projects advanced to the next phase of development. An instrument known as MOSFIRE—multi-object spectrometer for infrared exploration—moved from the construction phase into assembly and testing. Being built for the Keck 10-m telescope under the leadership of Ian McLean, this unique instrument can capture the infrared spectrum of up to 46 individual objects across a field of view of about 6 minutes of arc. It is one of the largest cryogenic infrared instruments ever built. The team is working towards a delivery in the summer of 2010. Meanwhile, a second instrument project led by James Larkin moved into construction. The Gemini Planet Imager (GPI) is a high-contrast imaging spectrometer being designed to work with an advanced adaptive optics system on the Gemini South 8-m telescope in Chile. GPI will provide diffraction-limited images and low-resolution near-infrared spectra in order to search young, nearby stars for the presence of giant planets lying close to their parent star. GPI will be delivered to UC Santa Cruz for integration with the adaptive optics system during 2010. Larkin and McLean are also involved in instrumentation development for the proposed new Thirty Meter Telescope (TMT). In collaboration with Caltech and UC Irvine and other groups, Larkin has continued to lead the design of IRIS, an infrared imaging system for the TMT.

This picture shows the large vacuum enclosure being assembled for MOSFIRE, the multi-object spectrometer for Infra-Red exploration. MOSFIRE is a large vacuum-cryogenic instrument for near-infrared (1-2.5μm) astronomy. It is being developed for the W.M. Keck 10-m telescopes by a team led by Ian McLean (UCLA) and Charles Steidel (Caltech). It can image a field of view of 6.1 arcminutes using a 4 Mpxl infrared camera and then deploy up to 46 small slits across the field to obtain spectra of all those objects simultaneously.

Together with other members of the department, Larkin and McLean were also involved in a faculty search for a young researcher with expertise in advanced infrared instrumentation for extremely large telescopes using adaptive optics systems. The search was successful and the Department looks forward to welcoming Dr. Michael Fitzgerald, a graduate of UCB who is currently a Michelson Fellow at the Lawrence Livermore National Lab, in 2010.

McLean continued as the director of the IR Lab at UCLA and as associate director of the University of California Observatories (UCO), which is led by Dr. Michael Bolte of UC Santa Cruz. Studying with Professor McLean, UCLA graduate student Emily Rice received her Ph.D. in June 2009 for work involving the comparison of observations and models of infrared spectra of very low-mass stars and sub-stellar objects called brown dwarfs. Emily has accepted a post-doctoral position at the American Museum of Natural History to work on related research with Dr. Ben Oppenheimer.

Extrasolar Planetary Systems: Ben Zuckerman and Michael Jura

Ben Zuckerman and graduate student David Rodriguez (UCLA) are working with the SMA's project's lead scientist Joel Kastner (Rochester Institute of Technology) and David Wilner (Harvard-Smithsonian Center for Astrophysics). Wilner is one of the world's experts on radiointerferometry, the technique used in this study. Using the Smithsonian Submillimeter Array (SMA) radio telescope system have revealed the

This artist's conception of the V4046 Sagittarii system highlights the disk-shaped molecular gas cloud imaged by the Submillimeter Array. The gaseous disk, which orbits the twin suns, shows that planets could form around double stars as easily as around a single star like our Sun. Credit: David A. Aguilar (CfA) presence of a rotating, molecular disk orbiting the younger binary star system V4046 Sagittarii. Images provide an unusually vivid snapshot of the process of formation of giant planets, comets, and Pluto-like bodies. The results also confirm that such objects may just as easily form around double stars as around single stars like our Sun. The SMA is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics and is funded by the Smithsonian Institution and the Academia Sinica. Young star research by RIT's Kastner and UCLA's Zuckerman and Rodriguez is supported by a grant from the NASA Astrophysics Data Analysis Program.

Michael Jura and Ben Zuckerman are co-leaders of the UCLA team of astronomers who have studied GD 362, a peculiarly dirty white dwarf star 165 light years away. Now they are pretty sure why the atmosphere of this dense, hot but slowly cooling ghost of a once much larger star is so polluted. It ate a planet. "We probably have a destroyed world here," says Jura. Apparently a planet with the mass of Mars — a billion trillion metric tons or so of rock, iron, dissociated water and other ingredients — was dismembered and atomized, its remains now bobbing in the thin but dense, 10,000 kelvins atmosphere that GD 362's powerful gravity holds close around itself. (*Excerpted from* Science News: The Star That Ate a Mars *by Charles Petit 07.08.09)*

An artist's conception shows how a superdense white dwarf star might pull apart a passing planet and incorporate its matter into Saturn-like rings. Illustration by Lynette Cook

Michael Jura and Michael W. Werner (SIRTF project scientist, Jet Propulsion Laboratory) are finding that there are planets where there were not supposed to be any. Among the most poignant sights in the heavens are white dwarfs. Astronomers think white dwarfs are probably not stars so much as the corpses of stars. A white dwarf was once much like our sun and shone with the same brilliance. Eventually it began to run out of fuel and entered its stormy death throes, swelling to 100 times its previous size and brightening 10,000-fold, before shedding its outer layers and shriveling to a glowing cinder the size of Earth. For the rest of eternity, it will sit idle, slowly fading to blackness. Astronomers have found more than a dozen white dwarfs in our galaxy that are orbited by asteroids, comets and perhaps even planets—entire graveyards of worlds. When the stars died, they vaporized or engulfed and incinerated their inner planets. Over time the dwarfs shredded and consumed many of the survivors as well. These decimated systems offer a grim look at the fate of our own solar system when the sun dies five billion years from now. (*Excerpted from* Scientific American: Unlikely Suns Reveal Improbable Planets *by Michel W. Werner and Michael A. Jura)*

Wide-field Infrared Survey Explorer (WISE): Edward (Ned) L. Wright

Edward L. Wright of UCLA is Principal Investigator of NASA's Wide-field Infrared Survey Explorer (WISE). WISE has been assembled and is undergoing final preparations for a planned November 1, 2009, launch from Vandenberg Air Force Base, California. The survey will be the most detailed to date in infrared light, with a sensitivity hundreds of times better than that of its predecessor. Among expected finds from WISE are hundreds of thousands of asteroids in our solar system's asteroid belt, and hundreds of additional asteroids that come near Earth. "We know that asteroids occasionally hit Earth, and we'd like to have a better idea of how many there are and their sizes," said Amy Mainzer of NASA's Jet Propulsion Laboratory. She is the mission's deputy project scientist. The infrared detectors on WISE will pick up the glow of roughly 1,000 brown dwarfs in our galaxy. "We've been learning that brown dwarfs may have planets, so it's possible we'll find the closest planetary systems," said Peter Eisenhardt, the mission's project scientist at JPL. Observations by WISE will guide other infrared telescopes to the most interesting objects for follow-up studies. It will orbit Earth, mapping the entire sky in six months after a one-month checkout period. Its frozen hydrogen is expected to last several months longer, allowing WISE to map much of the sky a second time and see what has changed. The mission was developed under NASA's Explorer Program managed by the Goddard Space Flight Center, Greenbelt, Md.

Left, a worker checks WISE spacecraft; right, the Wide-field Infrared Survey Explorer (WISE)

"Most of the sky has never been imaged at these infrared wavelengths with this kind of sensitivity; we are sure to find many surprises," says Edward (Ned) Wright.

Galactic Center Research Group: Andrea Ghez

Galactic Center research group has been using high angular resolution imaging to study both the supermassive black hole at the center of our Galaxy and brown dwarfs, which are thought to be the lowest mass products of star formation. The research highlight for this year is a project that is part of Tuan Do's thesis work. Using OSIRIS, which was built at UCLA by James Larkin, we have discovered that the distribution of old stars at the center of the Milky Way is inconsistent with theoretical models for how stars and a central supermassive black hole should interact. This surprising result suggests that black hole growth may be more difficult than previously thought.

Cover of Graduate Quarterly Spring 2008, Andrea Ghez research group

Several members of the group received nice fellowship positions and have moved on:

• Elise Furlan, who was at UCLA on an astrobiology postdoctoral fellowship, received a Spitzer Postdoctoral Fellowship, which she took to JPL (July 2008).

•Jessica Lu defended her Ph.D. September 25, 2008, and is now a Millikan Postdoctoral Scholar at Caltech.

• Andrea Stolte completed her postdoc position in July 2008 and now has an Emmy Noether Fellowship at the University of Cologne.

• Jorg-Uwe Pott finished his joint postdoctoral appointment (UCLA and Keck Observatory) in March 2009 and is now a researcher at the University of Heidelberg.

• Leo Meyer, who was at UCLA on a fellowship from the German government (DAAD, the German academic exchange service), finished his fellowship and returned to Germany for a job in the financial industry.

Andrea Ghez one of four panel members for "The Mysteries of the Cosmos," sponsored by the National Science Foundation, the Thirty Meter Telescope, and Discover magazine.

Andrea Ghez participated as one of four panel members that formed an astronomy round table on "The Mysteries of the Cosmos," which was sponsored by the National Science Foundation, the Thirty Meter Telescope, and Discover magazine. This event was the astronomy part of a larger series designed to increase the public's appreciation for science, with each event being aired in three venues. The first venue was a live discussion at Caltech's Beckman Auditorium in January 2009; the second was a feature article in Discover magazine (May 2009 issue); and third was a set of on-line videos from recorded pieces of the live event. (http://discovermagazine.com/events/mysteries-of-the-cosmos/)

Galactic Center Astronomy: Mark Morris

Mark Morris has continued his work on stars that are in their final death throes as they undergo the transition from red giant star to white dwarf by shedding much of their atmosphere in a strong wind, and in the process, lighting up the out flowing material to produce a so-called planetary nebula. With JPL colleague Raghvendra Sahai, he has used a large number of Hubble Space Telescope images of planetary and preplanetary nebulae to create a classification scheme for these objects based on their striking symmetries, and on the presence or absence of features indicating the action of various physical processes such as jets, rotation, or the influence of a nearby companion.

With recent UCLA thesis student Jon Mauerhan, Morris used a variety of infrared telescopes to discover a few dozen very massive stars in the central few hundred light years of our Galaxy. They were identified using a deep x-ray survey of the galactic center made with NASA's Chandra x-ray telescope. Most of these stars appear to be emitting x-rays because they are in binary systems containing two massive stars whose fast winds are violently colliding.

Morris continues to study the magnetic field near the galactic center, and in a recent radio study made with the Very Large Array radiotelescope in New Mexico, he and colleagues reported on magnetically organized features in the ionized gas flows around the central black hole, including an apparently helical geometry on small scales in one of the most prominent gas streams.

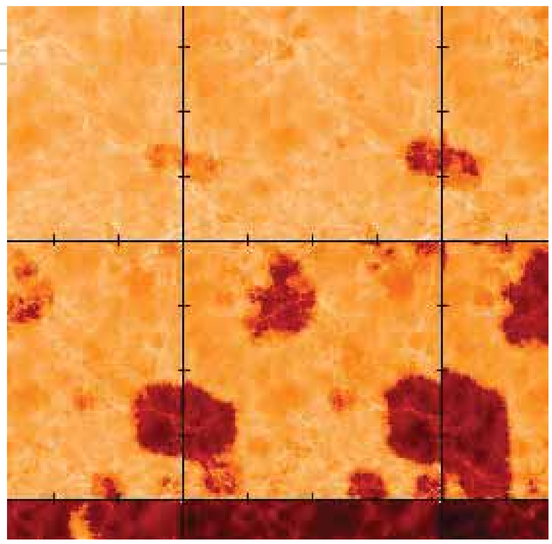
The Bug Nebula, NGC 6302, is one of the brightest and most extreme planetary nebulae known. The fiery, dying star at its center is shrouded by a blanket of icy hailstones. This NASA Hubble Wide Field Planetary Camera 2 image shows impressive walls of compressed gas, laced with trailing strands and bubbling outflows. Credit: NASA, ESA and A.Zijlstra (UMIST, Manchester, UK)

Galactic/Intergalactic Astronomy: Michael Rich

Michael Rich has led the Bulge Radial Velocity Assay (BRAVA) a program to investigate the space velocities of thousands of stars in the central bulge of the Milky Way. Graduate student Christian Howard received his Ph.D. in 2008, working on the project. The major finding is that the galaxy's central bulge is completely dominated by a flattened football-shaped population of stars called a "bar." There had been some speculation that the central bulge consists of two components, one young, and one old; the BRAVA survey finds only one component and puts other ideas to rest. Rich, collaborating with postdoc Andreas Koch, used the DEIMOS spectrograph on the Keck telescope, to complete a survey of stars in the outer halo of the Milky Way's neighbor galaxy, M31. The study shows that the outer halo of M31 is surprisingly metal poor, reaching 1/100 solar abundance, and extends to over 100 kpc. However, at about 150 kpc from the nucleus of M31, stars in the halo of M31's neighbor, M33, begin to dominate. In N-body simulations of a collision between a small satellite and M31, Masao Mori and Rich show that the collision could not have ejected stars from the M31 bulge and disk into the halo. Therefore, the metal rich stars observed in the inner halo of M31 must have originated in the smaller galaxy that collided with M31. The model also predicts that after 2 Gyr, a minor merger will scatter stars uniformly throughout the halo leaving no measurable trace behind. This was the first N-body simulation of an M31 collision with millions of stars modeling the disk, bulge, and halo of M31 as N-body structures (not static potentials) .

Theoretical Cosmology: Steven Furlanetto

Steve Furlanetto and graduate student Keri Dixon have studied the "reionization" of intergalactic helium by supermassive black holes about 12 billion years ago. This landmark event defines the moment when these luminous black holes influenced all the matter in the Universe, even though the black holes themselves remained quite rare. Furlanetto and Dixon have shown that the process is substantially more complex than previously thought and that new cameras now available on the Hubble Space Telescope should make remarkable progress in understanding this key era in galaxy formation.



The 21 cm transition of neutral hydrogen occurs when the spin of the electron flips relative to that of the nucleus. Although extremely weak (with a mean lifetime of 30 million years!), the enormous amount of hydrogen in the Universe makes it extremely useful for astrophysics. In particular, after the cosmic microwave background (CMB) last scattered (at z~1100) and before reionization, the Universe was full of neutral hydrogen

Astroparticle Physics: Rene Ong and Vladimir Vassiliev

The astroparticle physics group led by Rene Ong and Vladimir Vassiliev continues to conduct research in several areas of very high energy (VHE) astronomy and astrophysics. The main project is the Very Energetic Radiation Imaging Telescope Array System (VERITAS), an array of four 12m diameter telescopes that detect VHE x-rays in the energy range from sub-100 GeV to more than 10 TeV via the atmospheric Cherenkov technique. The VERITAS Observatory is starting its third observing season. During the last year, VERITAS extended the list of detected VHE sources to include an x-ray binary system in which a compact object (neutron star or a black hole) interacts with the gravitationally bound massive B star companion, several distant active galaxies. Perhaps two of the many thrilling VERITAS findings during the last year particularly stand out. The first is the discovery of diffuse VHE gamma radiation from the famous starburst galaxy Messier 82 (M82). It is believed that the unusually high rate of star formation in starburst region(s) of this galaxy results in the high rate of supernovae explosions of massive stars which in turn power cosmic ray acceleration and ultimately VHE radiation from this galaxy. M82 is the first object of the class of starburst galaxies from which VHE x-rays have been observed, and it is the first galaxy in which VHE cosmic rays outside of the Milky Way were indirectly detected. This finding is being published in the magazine *Nature*. Another major VERITAS scientific result published in the journal *Science* is the discovery of the outburst of VHE x-rays from the giant radio galaxy Messier 87 (M87), which was accompanied by a strong rise of the radio flux measured from the direct vicinity of its super-massive black hole. The UCLA group has a major role in three key science areas of the VERITAS project: a) astroparticle physics and detection of VHE x-rays from non-AGN sources, e.g., M82 and radio galaxies; b) sky survey of the galactic plane in the Cygnus region covering more than 100 square-degrees; c) search for the annihilation of dark matter particles in nearby galaxies. The VERITAS group at UCLA currently includes postdoctoral associate Amanda Weinstein and graduate students Timothy Arlen, Ken Chow, and Matthew Wood. During the last year postdoctoral associate Stephen Fegan moved to a new position at Ecole Polytechnique in Paris and graduate student Ozlem Celik graduated and took a position at Goddard Space Flight Center in Maryland. Looking beyond VERITAS, Vassiliev and Ong are also working to develop the next major ground-based VHE x-ray observatory, the Advanced Gamma-ray Imaging System (AGIS). AGIS will consist of 36 imaging atmospheric Cherenkov telescopes covering an area of one square kilometer. This next generation x-ray observatory has recently been proposed to the Astronomy and Astrophysics Decadal Survey 2010 Committee for construction in the next decade. The UCLA effort, led by Vassiliev, is concentrated on the design study of AGIS and on the development of a novel wide-field high angular resolution telescope using a design originally attributed to Schwarzschild and Couder. Significant work on the development of the novel telescope optical system is ongoing in the VHE astrophysics laboratory at UCLA, and the group is now seeking funding to expand this research and development effort.

VERITAS telescope at Fred Lawrence Whipple Observatory in Arizona. VERITAS x-ray observatory normally does not operate under moonlight. This spectacular photograph of the moon and its reflection from the VERITAS telescope mirror was taken by Stephen Fegan during calibration of the telescope positioning system. In a sense, however, this picture illustrates atmospheric Cherenkov light technique for the detection of x-rays. Every high energy photon interacts with the atmosphere and creates an avalanche (cascade) of secondary relativistic particles. These particles generate coherent polarization waves in the atmosphere know as Cherenkov light. The duration of the flash of Cherenkov light from cascade is only a few nanoseconds and Cherenkov telescopes make a photograph of the cascade with this short exposure to detect it against the night sky background.

Ong is also involved in two other exciting projects in astroparticle physics. The first is the Fermi Gamma-Ray Space Telescope (FGST) which is a major satellite observatory launched by NASA on June 11, 2008. Ong is also an affiliated scientist with the Large Area Telescope (LAT) team of Fermi. The second project is the future General Antimatter Spectrometer (GAPS) experiment. GAPS seeks to detect miniscule amounts of non-relativistic anti-deuterons in the cosmic rays. GAPS is in the development phase at the present time and is being funded for a long-duration balloon flight in the Antarctic during the early part of the next decade.

Astroparticle Physics:
Katsushi Arisaka, David B. Cline, Hanguo Wang

Katsushi Arisaka, David B. Cline and Hanguo Wang have been actively involved in the application of noble liquid detectors for dark matter.

A wide variety of observations now support a unified picture in which the known particles make up only one-fifth of the matter in the Universe, with the remaining four-fifths composed of unknown dark matter. One of the most promising techniques of direct detection is using liquid xenon, which was pioneered at UCLA by Cline and Wang back in early '90s. They founded the ZEPLIN collaboration and designed and built the ZEPLIN II detector at UCLA, then operated it at Boulby Mine, UK. The superiority of liquid xenon technology was further evidenced by the world's best limit set by the XENON10 collaboration led by Elena Aprile at Columbia University in 2007. The UCLA group decided to join the next phase of this group, XENON100 at the Gran Sasso Underground Lab in Italy. The detector construction has been completed and the detector is ready to take data very soon. So far, one postdoc Emilija Pantic and five graduate students—Artin Teymourian, Ethan Brown, Artin Teymourian Chi Wai Lam, Kevin Lung and Yixiong Meng—have joined the UCLA group, forming one of the largest dark matter groups in the U.S.

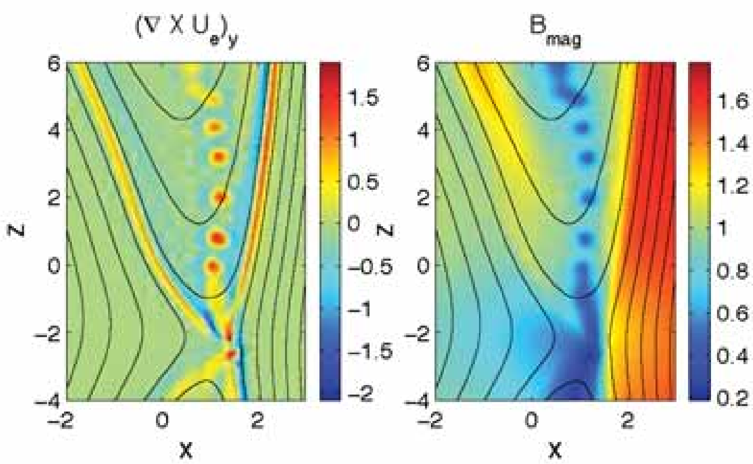
In parallel, early in 2007, Arisaka and Wang started to develop a new photon detector concept that allows background-free dark matter experiments at the multi-ton scale. Eventually this effort resulted in the invention of the QUPID (Quartz Photon Intensifying Detector) and XAX (Xenon-Argon-Xenon multi-ton experiment). Both concepts were presented at a series of meetings and conferences and published in *Astroparticle Physics*. This paper has studied systematically for the first time that a multi-ton dark matter detector can be constructed without any backgrounds. Based on this XAX concept, the MAX Multi-ton Argon Xenon international collaboration was formed for the U.S. DUSEL (Deep Underground Science and Engineering Laboratory), and the MAX engineering study funded by NSF has begun.

In addition to the dark matter search, Cline and Wang are active in ICARUS, a 600-ton liquid argon detector for proton decay and long base line neutrinos at Gran Sasso in Italy. Together with Arisaka, they have also joined the LBNE (Long Baseline Neutrino Experiments) project in the U.S. They will design a neutrino beam from FNAL to DUSEL, a 300k-ton scale water Cherenkov detector and a 100k-ton scale liquid argon TPC.

PTFE surrounds the liquid xenon to aid the reflectivity of scintillation light (peak wavelength of 174 nm), and the target is viewed by seven 5-inch photomultiplier tubes. This arrangement is contained within a copper vessel, surrounded by a roughing vacuum to minimize heat losses from convection.

Space Physics: Philip Pritchett, Ph.D. Researcher

Philip Pritchett has extended his particle-in-cell simulations of collisionless magnetic reconnection to the case of asymmetric reconnection where the asymptotic magnetic field magnitudes and plasma densities are unequal on opposite sides of the current layer. This case predominates at the terrestrial dayside magnetopause, in the heliosphere, and in most astrophysical settings. A new result has been observed for this case. In the presence of a guide magnetic field component, an electron velocity shear layer is formed on one side of the X line which emits a train of small-scale (less than the ion inertia length) electron vortices (see the figure). The vortices produce perturbations of ~30% in the ambient by field and propagate away from the X line at about 0.3vA. Together with Forrest Mozer from UC Berkeley, they have identified an example of such a large amplitude, short duration depression in the magnetic field during a magnetopause crossing by the THEMIS fleet of spacecraft.



Research Highlights

Nuclear Physics
Relativistic Heavy Ion and Intermediate Energy: Charles Whitten and Huan Huang

The UCLA Relativistic Heavy Ion and Intermediate Energy Physics Group is one of the leading research groups at Relativistic Heavy Ion Collider (RHIC), Brookhaven National Laboratory. The scientific goals are focused on studies of Quantum ChromoDynamics (QCD) under extremely high temperature and high density environment created in nucleus-nucleus collisions and on investigations of the gluon spin content of the proton using polarized proton-proton collisions.

The UCLA group has been active in STAR detector hardware construction since the founding of the STAR collaboration at RHIC, having participated in the construction projects of the Time-Projection Chamber (TPC) and the Barrel Electro-Magnetic Calorimeter (BEMC). We have reached a major milestone in our STAR detector upgrade program in 2009—the completion of the Time-of-Flight (TOF) upgrade project. The TOF detector covers the full azimuthal acceptance of the TPC and will be able to identify over 95% of charged particles in the acceptance. The TOF detector will greatly enhance STAR capability for measurements of strange baryons, heavy quark mesons, and event-by-event fluctuations in baryon number and strangeness production. The STAR TOF detector uses a new technology of Multi-Gap Resistive Plate Chambers (MRPC) for timing measurement. The MRPC modules have been manufactured by Chinese STAR groups with funding from Chinese agencies. The UCLA group has been collaborating closely with Chinese STAR groups, and Professor Huan Zhong Huang has been responsible for coordinating Chinese STAR effort. Dr. Vahe Ghazikhanian and graduate student Bertrand Biritz built the high voltage and low voltage systems for the TOF detector.

The spin physics program aims at measuring the gluon spin content of the proton. The group has been improving the precision of their asymmetry measurement of jet production in polarized p+p collisions, and their latest results indicate that the gluons in the proton do not carry a significant fraction of the total spin. They are investigating experimental measures which may be sensitive to orbital angular momentum of quarks. In addition, RHIC completed a successful commissioning run of polarized p+p at 500 GeV. The W boson production will be appreciable at this high energy. The future program will use the asymmetry in the W production to probe the spin polarization of the sea quarks in the proton.

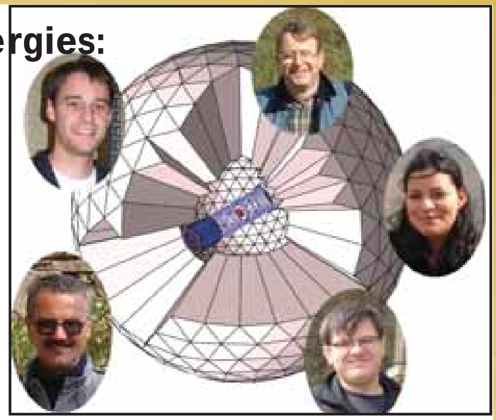
Image of TOF detector trays installed between the TPC and the BEMC in the STAR experiment

Graduate student Paul Sorenson Ph.D. (UCLA 2003), won the 2008 George E. Valley Jr. Prize from the American Physical Society "for his role in the discovery of quark number scaling in the elliptic flow of hadrons in nucleus-nucleus collisions, and its interpretation showing the relevance of quark degrees of freedom in heavy ion collisions," his thesis research topic at UCLA. In 2009 he won the Presiden tial Early Career Awards for Scientists and Engineers "for original research demonstrating quark number scaling in the elliptic flow of hadrons in nucleus-nucleus collisions that together with theoretical studies indicated the formation of a new form of matter—the strongly interacting quark-gluon plasma—and for service on the governing council of the STAR experiment."

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. Post-doctoral researchers are Aleksandr (Sasha) Starostin and Serguei Prakhov. Recently, 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. The subject of John Goetz doctoral thesis is to search for doubly strange nucleons using the improved CLAS detector at Jefferson Laboratory. John obtained the experimental data for his thesis in 2008, and he is now playing a crucial role in the preliminary analysis (or "cooking") of the data. Indara Suarez was awarded with the Postbaccalaureate Research Educational Program in 2008. In 2009, Indara was accepted to the graduate school of Texas A&M University. Beside preparatory work for a grad school, she is analyzing experimental data obtained at the University of Mainz where the group is spearheading a collaboration of some 12 Universities in research on multimeson photoproduction. Sriteja (Teja) Upadhyayula joined the group in 2009 as an undergraduate Research Assistant. Teja's primary responsibility is to maintain the group's Linux computer cluster, which is heavily used for the data analysis as well as for the Monte Carlo simulation.

The group pursues two experimental programs. One is centered around a special detector, the Crystal Ball multiphoton spectrometer, which has an acceptance of almost 4pi steradian. It has been installed in the 1.5 GeV tagged photon beam of the University of Mainz. This enables a measurement 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 to probe the structure of the proton. The second program uses the large CLAS 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 well suited to study the quark structure of the proton, probing the quark-quark correlations inside the proton.

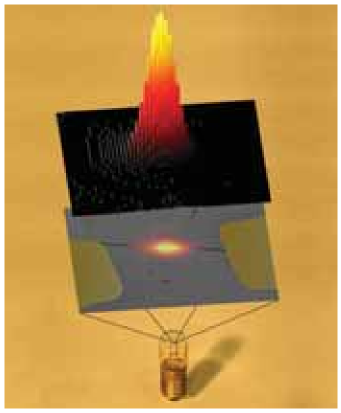


Members of the group (from upper-left, clockwise, John Goetz, Bernard Nefkens, Indara Suarez, Aleksandr Starostin, and Serguei Prakhov. Image from the cover of the *Physical Review Letters* (Phys. Rev. Lett. 100 (2008) 132301), highlighting the first Crystal Ball article from MAMI (ìIncoherent Neutral Pion Photoproduction on C12î,

Condensed Matter Physics: Gary Williams

A new luminescence pulse has been observed in collapsing bubbles in alkali salt solutions, published in *Physical Review Letters* 102, 204301 (2009). These bubbles are created by a pulsed laser. Previous observations in the lab in pure water had found a blackbody luminescence pulse emitted at the bubble collapse point, where the compression of the gas inside the bubble heats it to about 8000 K. When NaCl is added to the water, the new luminescence pulse is observed about 150 nanoseconds prior to the blackbody pulse and is found to be atomic line emission from the sodium atoms in the bubble, with the emission starting when the temperature in the bubble is about 2500 K. An interesting point is that a strong dependence of the timing of the sodium emission on the concentration of the NaCl solution could be explained by a theory of resonant radiation trapping of the sodium-line photons in the bubble, a theory first formulated in 1947 by the late UCLA professor Ted Holstein. This work was carried out in Prof. Williams' lab by Dr. Han-Ching Chu Czarnecka (a former graduate student), Sonny Vo (then an undergraduate, now in graduate school at Stanford), and Tim Hsieh (then a high-school student, now an undergraduate at Harvard).

Condensed Matter Physics: B.C. (Chris) Regan



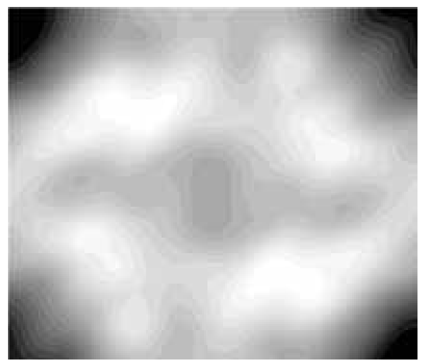
Artist's rendering of the two techniques used to "see" the carbon nanotube lamp in what's claimed to be the world's smallest incandescent light bulb. Visible light microscopy (top) and electron microscopy (middle). The nanotube filament is 1.4 micrometers long but only 13 nanometers (about 100 carbon atoms) in diameter. Credit: UCLA

Chris Regan has created the world's smallest incandescent lamp—so small it's invisible except when lit. The lamp's filament is just 100 atoms wide. It is made from a single carbon nanotube. When lit, the tiny bulb can be seen with the unaided eye as a point of light. Thomas Edison's light bulbs also used carbon filaments. But the new filament, created at UCLA, is 100,000 times narrower and 10,000 times shorter than those made by Edison.

The breakthrough comes at a time when we are moving away from incandescents, even looking beyond the green-leaning compact fluorescent bulbs (CFLs), and trying to figure out how to make LED lights cheap enough to take over the job of lighting homes and offices. The filament is big enough to apply the statistical assumptions of thermodynamics, which are longstanding rules about how stuff works when lots of particles are involved. Yet it is also small enough to be considered molecular, meaning the laws of quantum mechanics — involving very few particles — apply. "Because both the topic (black-body radiation) and the size scale (nano) are on the boundary between the two theories, we think this is a very promising system to explore." (*This work is funded by the National Science Foundation. Excerpt from the article "World's Smallest Light Bulb," created by Robert Roy Britt, editorial director of* Live Science.)

Condensed Matter Physics: Sudip Chakravarty

Professor Chakravarty continues to intensely study the recent experiments on quantum oscillations in high temperature cuprate superconductors. These experiments have the potential to change the entire landscape of this field. His other equally strong interests are (but not exclusively) quantum criticality, dissipative quantum phase transitions, and the role of von Neumann entropy and entanglement in many body quantum systems. Within the past year, Chakravarty and co-supervisor R. Bruinsma have graduated two Ph.D. students: Xun Jia (now a postdoctoral researcher at the Department of Radia tion Oncology at UCSD); and David J. Schwab (now a post doctoral researcher with the Princeton biophysics group). Among his recent awards and honors is Distinguished Scholar Prize shared with Professor C. M. Varma at UC Riverside "for their wide ranging contributions to condensed matter physics, in particular to strongly correlated systems" awarded by the American Chapter of Indian Physics Association. Chakravarty was named an Outstanding Referee by the American Physical Society. As of July 2009, he holds the first David S. Saxon Presidential Term Chair of Physics. His current research group consists of three graduate students and one postdoctoral scholar (David Garcia-Aldea), who comes from Madrid. He is particularly proud of his recent paper: "Resolution of two apparent paradoxes concerning quantum oscillations in underdoped high-Tc superconductors." (*Phys. Rev.* B 80, 134503, 2009). The journal has highlighted a kaleidoscopic image from this paper to be found at: http://prb.aps.org/kaleidoscope/prb/80/13/13450.



"An example of ARPES spectral function destroyed by disorder"

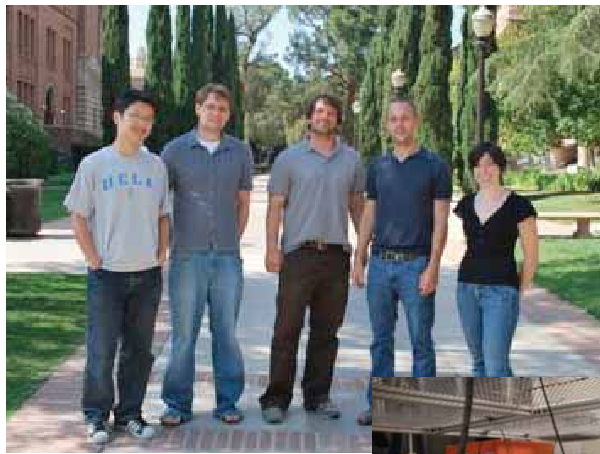
Atomic, Molecular and Optical-Physics: Eric R. Hudson

The group of Eric Hudson, the Department's newest faculty member, focuses on the study of quantum information and metrology, as well as tests of the foundations of fundamental physics. Towards these goals, Hudson is developing and implementing methods for trapping ultracold polar molecular ions. These trapped molecular ions, whose quantum states can be precisely engineered, provide a "clean" experimental system for the study of cold ion chemistry, precision measurement of molecular transitions, and the implementation of a scalable, quantum computation architecture.” In its first year of work, the group has managed to successfully produce and trap the candidate molecular ions and is now working on implementing their novel cooling method.

In addition to the molecular ion cooling and trapping experiment, a solid-state optical frequency standard, based on a low-lying transition in the ^229 Th nucleus, is being developed. Recent data indicates that this transition has the lowest energy of any known nuclear excitation, which should make it amenable to study by laser spectroscopy. Preliminary analysis indicates that this system may achieve an improvement in precision of as much as 10^6 over current optical frequency standards. The group was recently awarded a grant from UCOP to establish a long-term collaboration with Los Alamos National Laboratory, where the high-quality crystal host necessary for these experiments can be grown.

ERIC HUDSON GROUP

Funding: NSF and UCOP.



August 2009 Molecular Ion Theorum (MOT) under construction (funded by NSF)

Coherent Imaging Group: Jianwei (John) Miao

The Miao group continues to conduct cutting-edge research in three directions: coherent diffraction imaging (CDI), equally sloped tomography (EST), and high-speed imaging of biological systems. In CDI, they have developed a novel 3D imaging modality, denoted ankylography, which enables complete 3D structure determination from a single exposure. Based on theoretical analysis, numerical simulations and experimental results, they have demonstrated that when the diffraction pattern of a finite object is sampled at a sufficiently fine scale on the Ewald sphere, the 3D structure of the object can, in principle, be directly reconstructed from the 2D spherical diffraction pattern alone. This approach of obtaining complete 3D structure information from a single view is anticipated to find broad applications in the physical and life sciences. (see K.S. Raines, S. Salha, R.L. Sandberg, H. Jiang, J.A. Rodriguez, B.P. Fahimian, H.C. Kapteyn, J. Du and J. Miao, “Three-dimensional structure determination from a single view” *Nature*, in press.) Furthermore, as x-ray free electron lasers and other coherent x-ray sources are under rapid development worldwide, CDI has become one of the fastest growing fields in photon science (see a recent News & Views article by M.M. Murnane and J. Miao, *Nature* 460, 1088-90, 2009). In EST, the group has reconstructed a test phantom by using a UCLA megavoltage CT scanner and shown that EST improves the spatial resolution and the imaging contrast by at least 50% relative to the conventional tomographic method. In addition, the group formulated the EST approach as a constrained problem and subsequently transformed it into a series of linear problems, which not only significantly reduces the computational time, but also further improves the image quality (Y. Mao, B. Fahimian, S. Osher and J. Miao, *IEEE Trans. Image Process.*, in press). Finally, by using high-speed differential-interference-contrast microscopy with a millisecond timescale, the group (with Robijn Bruinsma and Kent Hill’s group) discovered a new model to describe the propulsion of Trypanosoma brucei, the causative pathogen for the fatal human disease African sleeping sickness. By quantitatively analyzing high-speed image sequences of cultured procyclic-form and bloodstream-form (BSF) parasites, as well as BSF cells in infected mouse blood, the group revealed that forward motility of T. brucei is driven by alternating left-handed and right-handed helical waves, denoted bihelical waves, that propagate along the flagellum and are separated by a topological kink. This work demonstrates that millisecond DIC microscopy can be a useful tool for uncovering important short-time features of microorganism locomotion (J.A. Rodríguez, M. Lopez, M. Thayer, Y. Zhao, M. Oberholzer, D. Chang, N.K. Kisalu, M.L. Penichet, G. Helguera, R. Bruinsma, K.L. Hill and J. Miao, *Proc. Natl. Acad. Sci.* USA, in press, 2009).

Miao Group 2009

Biophysics:
Katsushi Arisaka

Prof. Katsushi Arisaka continues to work on high-speed bio imaging, utilizing state-of-the-art photon detectors from particle physics. He keeps expanding his campus-wide collaboration. After successful operation of the world's fastest CMOS camera at Prof. Dolores Bozovic's lab, he applied the Image Intensified CMOS camera at Prof. Jack Feldman's lab at the medical school to visualize neural network activities. Collaboration with Photron (the world leader of high-speed cameras) was so successful that they donated three high-speed cameras to the CNSI core facility, where high-speed bio-imaging microscope systems have been established for everyone on campus.

With graduate student Adrian Chen, Arisaka also developed a high-speed two-photon excitation microscope at Prof. Carlos Portera-Cailliau's lab at the medical school. Again, this is the world's fastest microscope of its kind. Lastly, with graduate student Daniel Aharoni, Arisaka has developed 64 channel photon detectors at Prof. Shimon Weiss' lab in the bio-chemistry department to observe single molecule's high-speed motion in live cells. Based on the above successful collaboration, Arisaka is now aiming at establishing the Center for Neurophysics at UCLA, teaming with new faculty member Mayank Mehta.

Elementary Particle Physics:
Katsushi Arisaka, David Cline, Bob Cousins, Jay Hauser, David Saltzberg and Rainer Wallny

Pictured left to right: Florencia Canelli, Rainer Wallny, Bernd Stelzer and Peter Dong after the announcement of the discovery of single top production at Fermilab.

UCLA elementary particle physicists Katsushi Arisaka, Dave Cline, Bob Cousins, Jay Hauser, David Saltzberg and Rainer Wallny are using high energy particle accelerators to address the ancient question about nature's fundamental building blocks of matter and their interactions. Faculty colleagues Arisaka and Cline directly pursue the search for dark matter candidates with the XENON experiment. Also, the primary agent thought to give elementary particles their mass in the standard model, the Higgs boson, is still at large. The instruments to pursue searches for new physics beyond the standard model and the Higgs Boson are particle accelerators of the highest energy and intensity (luminosity). This year, Saltzberg and Wallny completed their research program at the Collider Detector at Fermilab (CDF), operating at the Tevatron Collider. They will join faculty colleagues Arisaka, Cline, Cousins and Hauser full-time at the high energy frontier on the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) at CERN, Switzerland.

Their involvement in CDF ended on a high note with several key publications in *Physical Review Letters* on the properties of the top quark, the heaviest known elementary particle. The top quark was only discovered last decade. Saltzberg and postdoc Charles Plager published their results on their search for the exceptional decay channel of the top quark, $t \rightarrow Zc$ using the CDF detector. An experimental distribution of this result is shown in the figure.

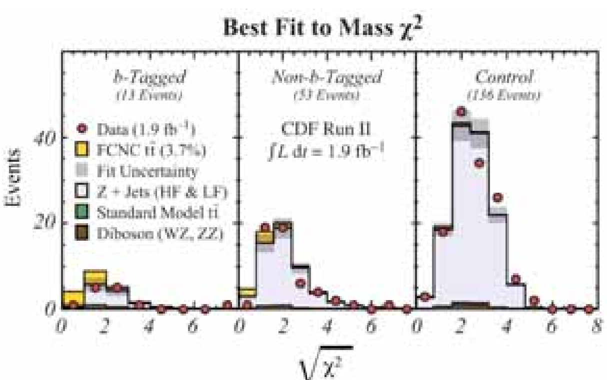


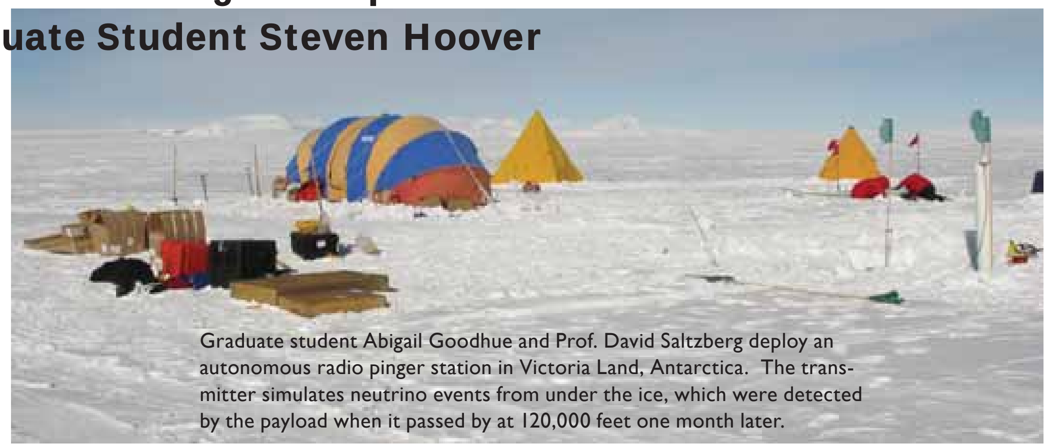
Figure 1: In the above image the yellow regions show the expected behavior of the rare decay $t \rightarrow Zc$. Other shaded regions show the behavior of known backgrounds. The data (red points) do not show any evidence of this highly forbidden decay.

With former postdocs Bernd Stelzer (Simon Frasier University, Canada) and Florencia Canelli (University of Chicago) and former graduate student Peter Dong (Illinois Mathematics and Science Academy), Wallny successfully completed a five-year search for a top quark production mode where top quarks are produced singly via the electroweak interaction rather than in pairs via the strong interaction. In March 2009, Wallny was given the honor of announcing the discovery of this process on behalf of the CDF collaboration.

Meanwhile, UCLA scientists have prepared their contributions to the CMS experiment for the first proton-proton collisions at the LHC at unprecedented energies. In September 2008, first beams were injected into the LHC accelerator with remarkable ease, but a damaging cooling incident later that month resulted in a year-long delay. Repairs of the machine expect that first collision data will be collected by the end of 2009. The involvement of UCLA physicists revolve around the unifying theme of muon detection at CMS. This past academic year also marks the third year of service of Bob Cousins as the Deputy Spokesman of CMS, the highest ranking position of a U.S. scientist in the CMS collaboration. Since mid-2008, researcher Gregory Rakness has led the entire commissioning effort of the muon endcap cathode strip (CSC) chamber detectors and coordinates the work of 50 scientists, engineers and technicians from many different institutions. The CSC chambers are now ready to see first collisions. Hauser with Rakness and postdocs Chad Jarvis and Amanda Deisher have spearheaded an effort to improve the internal timing and synchronization of the muon detection system. They also took over leadership in the upgrade projects dedicated to improving the CMS muon system for the SLHC high luminosity upgrade. Similar SLHC upgrade plans are being pursued for the inner layers of the CMS tracking system. With graduate students David Schaffner and Joseph Duris, Wallny showed that artificially produced diamonds are detector material that is radiation hard enough to withstand the expected SLHC radiation doses. With researcher Viatcheslav Valuev and graduate student Jordan Tucker, Cousins has used measured cosmic ray events to further refine the group's search for extra Z' gauge bosons using the CMS detector, including improvements to CMS standard track finding algorithms. Hauser and Jarvis have established a search for extra W' bosons; and Plager, Deisher and Wallny have joined forces to search for anomalies in event signatures, including leptons, jets and missing transverse energy, which could be indicative of a dark matter candidate particle.

ANITA Collaboration: David Saltzberg's Group
David Saltzberg, and Graduate Student Steven Hoover

The Saltzberg group (including post-doc Konstantin Belov and graduate student Abigail Goodhue), along with the ANITA collaboration, successfully built and launched the ANITA-II payload on a NASA long-duration balloon from Antarctica. ANITA-II spent over 30 days aloft, collecting data for evidence of ultra-high energy neutrinos striking the ice. The payload and data were fully recovered and the analysis is underway.



Graduate student Abigail Goodhue and Prof. David Saltzberg deploy an autonomous radio pinger station in Victoria Land, Antarctica. The transmitter simulates neutrino events from under the ice, which were detected by the payload when it passed by at 120,000 feet one month later.

Theoretical Elementary Particle Physics and Astrophysics: Alexander Kusenko

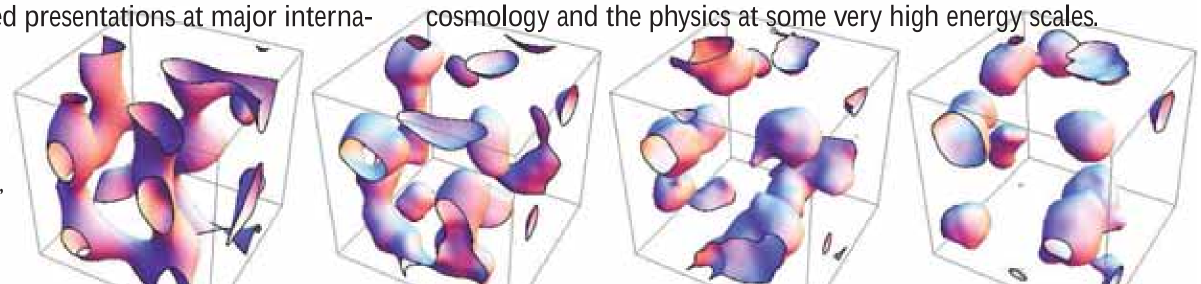
Alex Kusenko has joined Institute for Physics and Mathematics of the Universe in Japan as a senior scientist. The institute is a major new international research center that strives on synergy between physics, mathematics, and cosmology.

Kusenko has co-organized a number of activities at Aspen Center for Physics, as well as an international conference: SNOWPAC 2009: Snowbird Conference on Particle Astrophysics & Cosmology, which attracted many prominent speakers. UCLA graduate students Kalliopi Petraki and Ian Shoemaker gave talks on their original theoretical results published in leading physics' journals. Professor Kusenko was invited to give departmental colloquia at four leading universities, as well as several invited presentations at major international conferences.

In collaboration with Peter Biermann (U. Bonn) and Michael Loewenstein (NASA), Kusenko has conducted dark matter research using observation time on Suzaku and Chandra x-ray telescopes, which marks the first time these instruments were used in a dedicated search for dark matter. The first results have been published in *Astrophysical Journal*, and more results are in preparation.

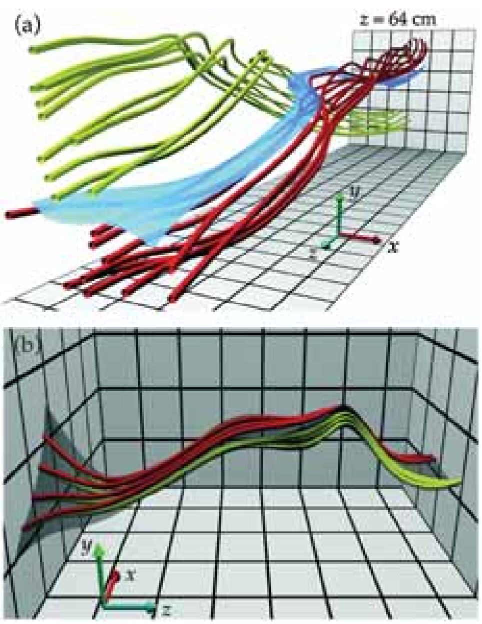
Supersymmetry in the early universe could manifest itself via primordial gravitational waves that can be discovered by the next generation of detectors. This novel idea was presented by Kusenko and collaborators in two papers published in *Physical Review Letters* and *Physical Review D*. These gravity waves can open a new window on Big Bang cosmology and the physics at some very high energy scales.

Three-dimensional evolution of the condensate on the N=64 lattice. Lumps of Q-matter are shown in color. The Q-matter breaks up into isolated lumps, Q-balls.



Large Plasma Device (LAPD) Plasma Group: Walter Gekelman

This year has been an active one for the LAPD plasma group. Graduate student Eric Lawrence has, for the first time, observed a quasi sepratrix layer (QSL) in an experiment on the LAPD. Magnetic energy in plasmas is often released through magnetic reconnection, a process where field lines break and reconnect to form a lower energy configuration. An experiment has been developed that provides the first application of a new theory of 3D magnetic reconnection to a laboratory setting. In LAPD, two parallel current channels collide and cause magnetic reconnection between them. A QSL (shown in blue in the figure) forms between them. QSLs have been used to identify reconnection sites in computer simulations and solar flare observations, but this recent work is the first experimental validation of the technique.



Magnetic field lines from current channels in the LAPD in red and yellow; quasi-separatrix layer between them in blue.

Andrew Collette has achieved another first: Using a precise probe drive system, he constructed magnetosonic waves observed in the interior of an expanding laser produced plasma. A third first has been achieved by Brett Jacobs who has measured the ion distribution function as a function of space and time above a silicon wafer in a plasma etch tool. The tool was donated by industry and is part of a cooperative experiment. The plasma group has investigated the interaction of Alfven waves with trapped electrons in a magnetic field well in a project that involves the University of Maryland and Stanford University. Patrick Pribyl, Walter Gekelman, Bart Van Compernolle, and new graduate student Yuhou Wang are involved. Two members of the research group-–Shreekrishna Tripathi and Patrick Pribyl— have developed an ion source and with Gekelman, are doing experiments in which the 22 KeV ions radiate Alfven waves in a background plasma. Other experiments, performed by Stephen Vincena and Gekelman, include laser produced plasma jets and characterization of the dense toroidal plasma discussed in the feature article "Sun in a Box." Finally Vincena, Jim Maggs and George Morales are engaged in experiments of plasma wave propagation in plasma with several species of ions.

Plasma Diagnostic Group (PDG): Dr. Tony Peebles

Over the last year, research highlights include completion of successful experiments at DIII-D to test and validate nonlinear gyrokinetic turbulence predictions via comparison with multi-field turbulence profile measurements. The first experiment was led by former graduate student Anne White (Ph.D. 2008) who developed a local measurement of electron temperature fluctuations on DIII-D by correlating electron cyclotron emission from two spatially adjacent locations. This allowed thermal noise emission to be decorrelated, while revealing the underlying temperature fluctuations. The technique was combined with measurements of local density turbulence to simultaneously measure the spatial profile of both density and electron temperature fluctuations. The data was compareed to predictions from nonlinear gyrokinetic simulation codes. Excellent agreement was found deep in the plasma core, but further towards the edge, predictions departed from experimental observation. More recently, research at DIII-D has focused on measurement of the phase relationship between temperature and density fluctuations, which provide a more fundamental and rigorous test of the validity of nonlinear transport simulation models. The PDG is active in developing diagnostic systems for ITER (http://www.iter.org/default.aspx), a multibillion dollar international investment in a collaborative research and development project that aims to demonstrate the scientific and technical feasibility of fusion power.

Inside the DIII-D tokamak fusion plasma

Computer Simulations of Plasma Group

Warren B. Mori, Viktor Decyk, Philip Pritchett

The computer simulations component of PDG continues to do pioneering work in high-performance computing of complex plasma phenomena. The group includes two research physicists, two post-doctoral researchers, researchers, and six Ph.D. students. 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 35,000 processors on some of the worlds fastest computers.

The group has received several INCITE awards, which provide access to the largest computers managed by the Department of Energy (DOE). The group is also affiliated with DOE's Scientific Discovery through an Advanced Computing (SciDAC) grant titled Community Petascale Project for Accelerator Science and Simulation (COMPASS) as well as a DOE Fusion Science Center (FSC) grant on Extreme states of matter and fast ignition physics.

The group is also engaged in carrying out three-dimensional simulations with the full temporal and spatial scale of both ongoing plasma-based accelerator experiments as well as conceptual designs of such accelerators that are well beyond the reach and cost of existing experiments. Recently, the DOE has approved the construction of a new facility called FACET at the Stanford Linear Accelerator for testing the feasibility of plasma-based accelerator technology as an alternative to building future linear colliders. The group is actively engaged in carrying out possible experiments to be carried out at this new flagship facility. Recently, the group collaborated on developing the capability to perform simulations in a Lorentz boosted frame. In some cases, this reduces the computational costs by a factor of g2 where g is the Lorentz factor for the boosted frame.

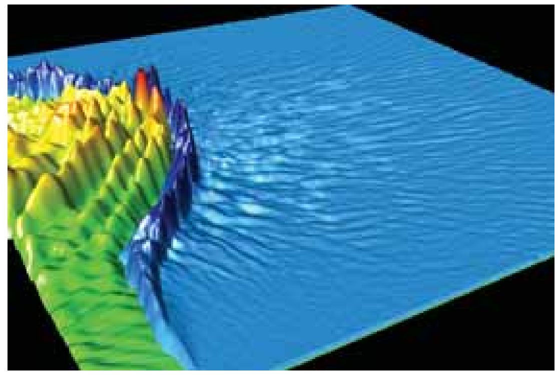
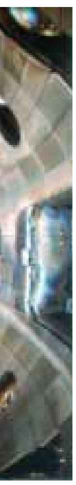


Figure: The plasma density compression as an intense laser impinges on a plasma with solid density taken from a particle-in-cell simulation. A shock is launched into the plasma.

The group is also actively engaged in simulating laser plasma interactions of interest to inertial fusion energy. For example, the group has been studying what happens when Petawatt class lasers with 10s of Kilojoules of energy hit highly compressed matter. We find that relativistic shocks can be launched that have analogous properties as in astrophysical settings. An example from a simulation is shown in figure. In addition, they are studying nonlinear plasma waves that can be excited when a laser propagates in a plasma. These plasma waves consist of trapped and untrapped electrons, and they can form complex phase space structures.

The PDG has produced outstanding students: One recent graduate, Dr. Chengkun Huang, received the 2007 Nicholas Metropolis Award. This is the best thesis prize given by the Division of Computational Physics within the American Physical Society. Two other recent graduates, Dr. Wei Lu and Dr. Michail Tzoufras, received the 2007 and 2009 John Dawson Thesis Prizes respectively. This is the best thesis award given in the area of plasma-based acceleration.

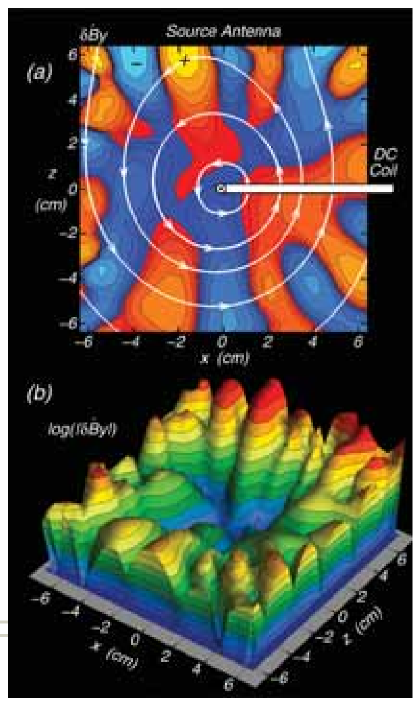


Basic Plasma Physics:

Reiner Stenzel and Manuel Urrutia

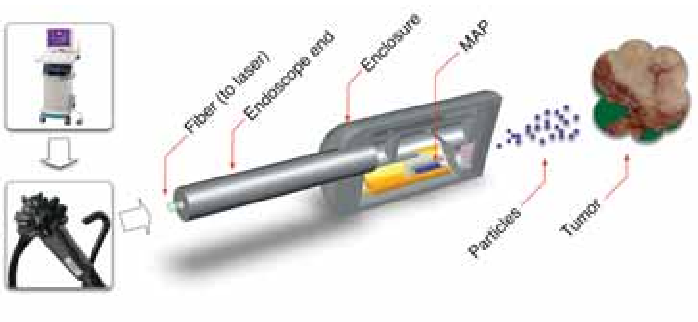
Research on whistler modes in plasmas led to a new discovery of eigenmodes on closed magnetic field lines, shown in the figure. These modes are analogous to Alfven eigenmodes in magnetospheric plasmas or toroidal fusion devices. The whistler modes are excited by a small coil located near the null point of a dc background magnetic field which contains closed field lines around a Helmholtz coil as indicated in white in the upper picture (a). The whistler waves, indicated by contours of wave magnetic field dBy/dt, propagate around the closed field lines and form standing waves in the azimuthal direction. The standing wave pattern is also displayed in the lower picture (b) showing the magnitude of the wave field on a logarithmic scale.

An interesting feature of whistler modes is their helicity: It is positive for propagation along the background field and negative for propagation against the background field. Therefore, standing waves, containing both directions of propagation, consist of whistlers without helicity. In the present case, a fixed frequency is imposed resulting in a mode number given by the wave dispersion relation. Alternatively, for broadband noise excitation, spatial eigenmodes would select preferred resonant frequencies. Resonance phenomena are of interest in space plasmas, heating and plasma diagnostics.



Accelerator Beam Physics:
Gil Travish, Researcher

Dr. Gil Travish's innovative Micro Accelerator Platform (MAP) project is working to develop a particle accelerator on a chip with accelerating gradients reaching 1 GeV/m. This laser-powered all-dielectric structure has applications in high energy x-ray production that would be suitable for cancer therapy (see figure), industrial inspection, and security applications. Travish has received a three-year grant from the Defense Threat Reduction Agency (DTRA) to support the basic research and develop a prototype. The project was also awarded an access grant from the Los Alamos Center for Integrative Nanotechnology (CINT)—a facility with the capabilities of fabricating the challenging structure. An extension of the MAP to structures relevant to high energy physics colliders is being performed collaboratively with UCLA spin-off RadiaBeam Technologies through a DOE Phase II SBIR and will be tested at SLAC's E-163 facility.



A conceptual drawing of the Micro Accelerator Platform encapsulated at the tip of a fiber endoscope as envisioned for use in minimally invasive cancer therapy

In a related development, Travish is developing micro scale electron sources based on pyroelectric crystals. These sources have direct application in lab-on-a-chip uses as well as compact x-ray sources. The application of these sources to a scanning electron microscope (SEM) is being explored by summer REU student David Fong (Occidental College).

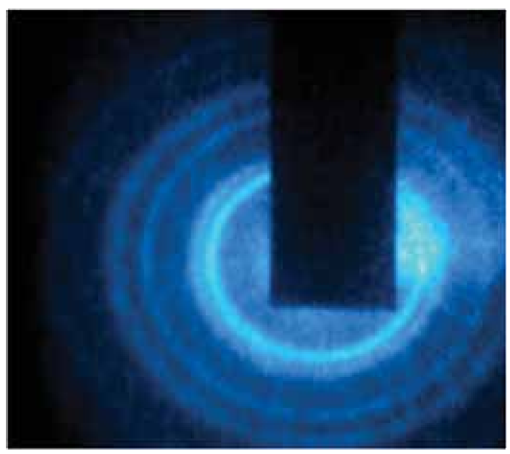
In addition to undergraduate students Ninel Vartanian and Esperanza Arab, graduate student Josh McNeur recently joined the team. This work is being performed in collaboration with Prof. Rodney Yoder (formerly at UCLA and now at Manhatanville College).

Accelerator Beam Physics:
Pietro Musumeci

Pietro Musumeci continues his work on mixing the novel high-power ultrafast laser techniques with classical accelerator and beam physics.

The Inverse Free Electron Laser, a high gradient acceleration technique for which UCLA still holds the world record for highest energy gain and gradient, is recently at the center of renovated interest. In particular, there are few applications for beams in the few GeVs energy range for which the IFEL could be an ideal compact injector. They include gamma ray production by inverse Compton scattering or soft x-ray production by Free-Electron Lasers. Two UCLA-led proposals at the ATF facility at BNL and at the SPARC/FLAME facility in Frascati, Italy, have been approved, and experiments will start in 2010.

The on-campus program is focused on the generation and manipulation of ultrafast electron beam at the Pegasus photoinjector laboratory. With graduate students Josh Moody and Cheyne Scoby, progress has been made in pushing the barrier of ultrashort electron beam physics across the sub-100 fs boundary. In the quest for using such beams for dynamically resolve structural changes at atomic scale with sub-100 fs time resolution by ultrafast electron diffraction, the laboratory has implemented various advanced diagnostic tools to monitor the beam at such short time scales. This year efforts resulted in the first demonstration of time resolved relativistic electron diffraction. The figure is an example of a high quality diffraction pattern from a polycrystalline aluminum sample obtained with a single shot of the Pegasus photoinjector beam. The position, width and intensity of the diffraction rings reveal the information on the crystal structure. By studying the change in the diffraction pattern a given time after a pump laser pulse has shocked the sample, one can obtain a real-time view of the rearrangement of the crystal structure with atomic spatial resolution.



Diffraction pattern obtained by sending a 3 MeV beam onto a 100 nm thick polycrystalline aluminum foil. Being able to obtain a high quality diffraction pattern with a single shot of a 100 fs electron beam is a major advantage of the relativistic ultrafast electron diffraction technique.

Faculty 2008-2009

Professors

Elihu Abrahams (Adjunct Prof.)
Katsushi Arisaka
Maha Ashour-Abdalla
Zvi Bern
Stuart Brown
Robijn Bruinsma
Charles Buchanan -
Vice Chair of Academic Affairs
Sudip Chakravarty
David Cline
Ferdinand V. Coroniti -
Department Chair
Robert Cousins
Steven Cowley
Eric D'Hoker
Sergio Ferrara
Christian Fronsdal
Walter Gekelman
Graciela Gelmini
Andrea Ghez
George Grüner
Jay Hauser
Kàroly Holczer
Huan Huang
Hong-Wen Jiang
Michael Jura
Per Kraus
Alexander Kusenko
James Larkin
Matthew Malkan
Ian McLean
George J. Morales
Warren Mori
Mark Morris -
Vice Chair of Astronomy and Astrophysics
Bernard M. K. Nefkens
William Newman
Rene Ong
C. Kumar N. Patel
Roberto Peccei –
Vice Chancellor for Research
Claudio Pellegrini
Seth J. Putterman
James Rosenzweig -
Vice Chair of Resources
Joseph A. Rudnick -
Acting Dean of Physical Sciences
David Saltzberg
Reiner Stenzel
Terry Tomboulis
Jean Turner
Roger Ulrich
Charles A. Whitten
Gary A. Williams
Edward Wright

Associate Professors

Troy Carter
Michael Gutperle
Brad Hansen
Jianwei Miao
Thomas Mason
Alice Shapley
Vladimir Vassiliev
Rainer Wallny
Giovanni Zocchi

Assistant Professors

Dolores Bozovic
Steven Furlanetto
Eric Hudson
Pietro Musumeci
Christoph Niemann
B. Chris Regan
Yaroslav Tserkovnyak

Professors Emeritus

Ernest S. Abers
Eric Becklin
Rubin Braunstein
Nina Byers
Marvin Chester
Gilbert W. Clark
John M. Cornwall
Robert Finkelstein
Roy Haddock
George Igo
Leon Knopoff
Steven Moszkowski
William E. Slater
Alfred Wong
Chun Wa Wong
Eugene Wong
Byron T. Wright
Benjamin Zuckerman

Researchers

Researchers

Viktor Decyk
Weixing Ding
Samim Erhan
Anthony Lin
James Maggs
William Peebles
Philip Pritchett
Terry Rhodes
R. Michael Rich
Steven Trentalange
J. Manuel Urrutia
Hanguo Wang

Associate Researchers

Sven Reiche
Lothar Schmitz
Gil Travish
Stephen Vincena

Assistant Researchers

Luca Bertello
Carmen Constantin
Neal Crocker
Xiaoping Ding
Yasuo Fukui
Sarah Gallagher
Mikhail Ignatenko
Nandini Mukherjee
Shoko Sakai
Alexsandr Starostin
John Tonge
Frank Tsung
Shreekrishna Tripathi
Bart Van Compernolle
Jeffrey Zweerink

department news

NEW FACULTY

MAYANK MEHTA

UCLA is pleased to welcome Mayank Mehta who accepted joint appointments in the Department of Physics and Astronomy and the Department of Neurology as an associate professor in summer 2009. He comes to UCLA with an impres sive CV.

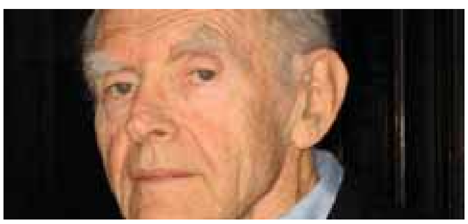
Mehta completed his doctoral studies in the path-integral formulation of computing anomalies in supersymmetric theories, discovering a one-parameter family of Dirac equations and developing a novel method for Euclidean continu ation of fermions.

Following his Ph.D., Mayank pursued postdoctoral studies at Hebrew Univer sity, the University of Arizona, and M.I.T. During this period, Mayank studied both experimental and theoretical neurobiology. His research focused on under standing the emergent properties of neural ensembles and neural mechanisms of learning and memory. From 2003 to 2009, he was an assistant professor at Brown University.

He has published more than 20 papers in physics and neurobiology and currently has several publications under review. He has been an invited speaker at numerous events since 1996. At this time, Mayank is principle investigator on four grants: Advanced Bionics (2008-20009); NSF Faculty Early CAREER Development Award (2006-2011); NARSAD Young Investigator Award (2006-2009); and Whitehall Foundation (2009-2012).

His laboratory measures the activity patterns of ensembles of neurons from multiple brain regions during behavior and during sleep. His recent studies have focused on how multiple brain regions, or neuronal networks, interact with each other during behavior and sleep; how these interactions would result in learning; and what the emergent prop erties of such interaction would be.

ELIHU ABRAHAMS



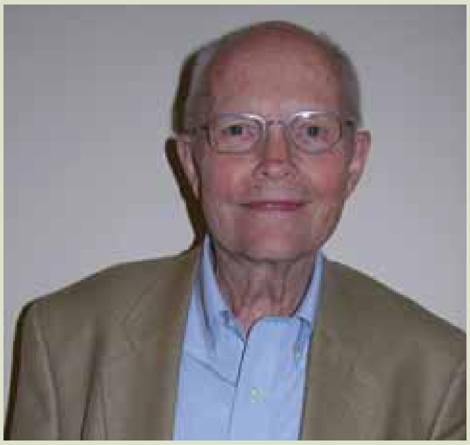
We are proud to announce that Professor Abrahams, a theoretical condensed matter physicist, has joined the UCLA physics department as a distinguished adjunct professor. Among his many awards and honors are memberhips in the National Academy of Sciences and the American Academy of Arts and Sciences. He has been a member of the board of trustees at the Aspen Center for Physics for many years and has also served as its president. He continues to play an active role there as an honorary trustee and has helped shape the agenda for condensed matter physics for decades. He comes to UCLA from Rutgers University, where he is currently the director of the Center for Materials Theory. His current interest is the newly discovered iron-based high temperature superconductors called the pnictides. His 1979 seminal paper, “The Scaling Theory of Localization,” with co-authors P. W. Anderson, D. Licciardello, and T. V. Ramakrishnan, revolutionized the field. The number of citations to this paper in the ISI Web of Science is currently 3,380 (an average of more than 100 per year). Abrahams is a spectacular addition to the Department, in particular to the condensed matter theory group.

IN MEMORIAM

RICHARD (DICK) EYRE NORTON 1928-2008

Dick Norton bought his last car four years ago—a sleek Maserati coupe that could do 180 miles an hour. Not the usual choice for a 76-year-old retiree. But then, Dr. Norton was never a conventional man.

Friend and colleague Richard Eyre Norton died October 28 in Santa Monica, California, after a two-year battle with cancer. He was 80. Dick was born March 2, 1928, in New York City. He grew up in Westchester County, New York, and built a formidable academic resume: undergraduate degree from Lehigh University; Ph.D. in physics from the University of Pennsylvania; and post-doctoral research work at Cal Tech.



In 1960, he joined the faculty of UCLA's Department of Physics, taught for 30 years, and retired in 2000. His specialty was elementary particle physics.

When the Aspen Center for Physics, a research center for theoretical physicists, was founded in 1961, Dr. Norton was one of the first participants. At the time of his death, Dr. Norton was finishing work on a text called *Complex Variables*. Mrs. Norton says a colleague plans to complete the book, slated for publication by Oxford University Press. *(Excerpted from* Rocky Mountain News *by Bill Gallo)*

CURT CLAYBOURNE HAMBLIN 1923-2009

Curt joined the Department in 1956 and for nearly 50 years, working in the research stores, cheerfully procured and distributed supplies to researchers working in the labs in Knudsen and Kinsey halls. A true oral historian, Curt knew everyone in the Department: faculty and staff—and their families. Curt would recall the Department's history and tell the stories—some may have wished he had forgotten. Curt's work ethic and personal dedication will forever linger in the labs.

Curt truly loved everything about UCLA and when he retired in 2008 at the age of 85, the Department lost a dear friend. Curtis finally passed away at the age of 86 and will be loved and remembered by all his friends.

Curt celebrating his 80th birthday

Congratulations to Brent Corbin who was awarded one of UCLA's Distinguished Teaching Awards for non-senate faculty.

March 29, 2008
Chavez Memorial March

The UCLA Plasma Science and Technology Institute again sponsored a booth at the community fair held at the end of the Chavez Memorial March on Sunday, March 29. The effort was organized by Dr. J. Manuel Urrutia with the assistance of Professors Reiner Stenzel, Charles Whitten, and Troy Carter; research faculty Dr. Frank Tsung; and Dr. Martin Simon, who was in charge of the Department's lecture demonstrations. Physical principles were demonstrated to children and their parents through a hands-on approach. As in years before, the presentations were well received by the community.

Professor Troy Carter showing young people and parents the "magic" that is physics

Research Experience for Undergraduates (REU) - Summer 2009

Francoise Quéval, Mark Morris and the REU group 2009 at Mt. Palomar.

The Department hosted its seventh summer research group for top university physics students from around the country. This program is sponsored by the National Science Foundation's Research Experience for Undergraduates (REU). In total, the Department has hosted 92 summer students over the years. The REU program is based on the notion that a genuine research experience is the best way to inspire students to pursue careers in science. Indeed, many of these students come from schools that have no research facilities; so for these students, this is their first encounter with the world of research. The experience has a tremendous and positive impact in their decision to choose a science career. Among the many academic and social activities that make up the REU experience, the program includes a camping trip to Mt Palomar and a visit to the observatory there.

Career Night April 13, 2009

On April 13, 2009, the Department sponsored its annual career night during which a number of distinguished alumni from a variety of walks of life came to talk about the myriad of opportunities for careers in physics. The event was extremely well attended by both undergraduate and graduate students, as students are always glad to get a first-hand description of the working world. Students left reassured and with a vision that their physics background prepares them for a broad variety of interesting careers.

Dr. Anne White (Ph.D. graduate UCLA 2008) was recently selected by the American Physical Society to receive the 2009 Marshal N. Rosenbluth Outstanding Doctoral Thesis Award. The award provides "recognition to exceptional young scientists who have performed original thesis work of outstanding scientific quality and achievement in the area of plasma physics."

Dr. Anne White

UCLA Department of Physics and Astronomy Workshops

The Department hosted five workshops in 2008-09. In November 2008, a one-day West Coast LHC theory meeting was held at the Faculty Center, organized by Harald Ita, Zvi Bern and Rainer Wallny. During the first week of January, the Center for Multiscale Plasma Dynamics and the Center for Magnetic Self-Organization hosted the 2009 Winter School. This is a very popular event, attracting students from all over the world. The workshop is based on "Common Themes in Space, Astrophysical and Laboratory Plasmas." Also in January, the particle beam physics group held a workshop titled "High Average Power & High Brightness Beam," organized by Gil Travish, John Lewellen and Aaron Tremaine. The main topic was the challenges in production and acceleration. Once again in January, the nuclear physics group, consisting of Huan Huang and Charles Whitten, held a workshop titled "Heavy Quark Physics in Nucleus-Nucleus Collisions." The Department was workshop-free until May 2009, when it was the host for "X-ray Science at the Femtosecond to Attosecond Frontier," organized by David Attwood (UCB), William Barletta (USPAS/MIT/UCLA), Fulvio Parmigiani (Universita' di Trieste), and Claudio Pellegrini (UCLA). All of the workshops were a huge success.

Program for Excellence in Education and Research in the Sciences (PEERS)

The Program for Excellence in Education and Research in the Sciences (PEERS) began in fall 2003, originally directed by Charles Buchanan in the Department and as of July 2009, by Paul Barber in the UCLA Department of Ecology and Evolutionary Biology. The program is flourishing.

Each year PEERS begins with 70-90 freshmen in the physical and life sciences who enter UCLA with good records of academic achievement, but with more than average life challenges—students with good prospects at UCLA and the potential to be very good scholars and researchers; 60% to 70% are the first generation to go to college. PEERS opens doors for these students, who typically enter UCLA not knowing a great deal about what a strong research university can offer other than courses.

PEERS provides a potpourri of synergistic education elements: collaborative learning workshops in introductory courses in math, chemistry, physics and life sciences (supervised by Brent Corbin in the Department); a freshman seminar on the transition to UCLA and college-level study skills in the fall; individualized counseling; a sophomore seminar on majors and careers in the fall; two or three research talks per quarter by charismatic professors; and the opportunity to get into significant undergraduate research. The students bond into the "PEERS community" with the result that the whole seems to be greater than the sum of its parts.

The results have been extremely encouraging: 60% to 70% finish the two-year PEERS program as science majors, with GPAs averaging 3.2 to 3.4; and 40% to 60% of these students get into undergraduate research by their sophomore year. They become contributing members of the UCLA scientific community by the time they graduate. Several have won prestigious national awards. Typically 30% matriculate to graduate or professional school with offers from Stanford, MIT, Cal Tech, UCLA, Boston University, UC Davis, to list a few. These results exceed studies of comparable control groups by roughly an order of magnitude.

PEERS has been sufficiently successful that Judi Smith, vice provost for undergraduate education at UCLA, is now leading a process of "institutionalizing" PEERS, in order to weave it more permanently into the fabric of the university.

Fellowships...

GAANN Fellowship Recipients

Six incoming students have been awarded the GAANN (Graduate Assistance in Areas of National Need) fellowship. Funded by a grant from the Department of Education, the 2009-2010 fund will support the following students: Anton Bondarenko, Asher Davidson, Christopher Farrell, Antonio Russo, Edward White, and Lauren Wozniak Pearce.

Selection for this award is competitive and based on financial need and academic ranking. Earlier in the Ph.D. program, recipients of this fellowship are encouraged to seek research opportunities and are required to participate in a scientific writing course with Professor Eric D'Hoker.

Dissertation Year Fellowship Program

The University of California's Dissertation Year Fellowship Program provides support to outstanding Ph.D. candidates during their final year of graduate school––support that allows them to focus on writing their dissertations. The program is designed to identify doctoral candidates who have been educationally or economically disadvantaged or whose research or planned career direction focuses on problems relating to disadvantaged segments of society. This program assists students by providing faculty mentorship as they prepare to become postdoctoral fellows or candidates for faculty positions. This year's fellowship recipients chosen from the Department are: Xun Jia, Henrik Johansson, Quinn Konopacky (Astro), and Alaina Henry (Astro).

Graduates 2008-2009

BS in Physics

James Adams
Francisco Alfaro
Roger Asfahan
Kochise Bennett
Ibrahim Boulares
Daneil Brady
Jacqueline Brosamer
Halley Brown
James Brugger
Michael Chang
Evan Ching
Nicole Ciccarello
Anthony Correia
Tyler Dawson
David Dreisbach
Mark Eberstein
Sean Eggers
Hossein Fard
Michael Goldflam
Antonia Hubbard
Sung Min Hwang
Emma Ideal
Elliot Karlin
Hyun Kim
Anshul Kogar
Kenji Kusuma
Michael Lee
Irina Lev
Moran Levi
Tommy Li
Nicholas Lytal
Daniel Margala
Alex Miller
Nickolas McColl
Pardis Niknejadi
Reiko Okumoto
Richard Patterson
Erik Perez
Christopher Reilly
Lauren Reed
Praveen Rudraraju
Gevik Sarkissian
Andres Saucedo
Craig Schallhorn
Kartik Vasan
Extra Ladd Von Nothaus
Theodore Walter
Xiaoyu Zhu

BA in Physics

Emin Avakian
Katherine Koziar
Ken Nakatsukasa
Alysia Yamada

BS in Astrophysics

David Ahnger-Pier
Marc Child
Andres Madden
Seth Meeker
Tiffany Meshkat
Marissa Rosenberg
Jonathan Wang

BS Biophysics

Aria Asghari
Tiffany Chen
Paul Hsu
Rachel King
Paul Leonor
Shreyas Patel
Martin Dean Strotz Von Moos
Mario Urnadeta-Moncada
Zhiong Wang

Bill Prady

Graduation Day 2009, June

Family, friends, faculty and staff joined in celebrating the wonderful accomplishments of the graduating students in physics and astronomy on Saturday, June 13, 2009, at 4:00 p.m. in Schoenberg Hall. This was the largest graduating class in recent memory, and those filling the hall radiated a spirit of excitement and anticipation of the new adventures awaiting the graduates. The Department Chair, Ferdinand Coroniti, welcomed everyone to the commencement celebration, which was followed by the procession of the students onto the stage. Acting Dean Joseph Rudnick presented the Rudnick-Abelmann Scholarships to Breann Sitarsky and Oswaldo Alvarenga. Student addresses were given by Emma Ideal, graduating with a B.S. in biophysics, and Eric Wang, a Ph.D. graduate in plasma physics theory. The keynote speaker was Bill Prady, the executive producer and co-creator of the TV sitcom "The Big Bang Theory." His speech was a perfect blend of light humor and wise counsel. The graduating students were then presented by Professor Michael Jura and Chairman Coroniti, and those receiving doctorates participated in the hooding ceremony. It was a joyous and proud occasion for all.

DOCTORAL DEGREES AWARDED

Accelerator
Alan Cook
Michael Dunning

Astronomy
Xi Chen
Alaina Henry*
Jessica Lu
Jon Mauerhan
Emily Rice
Tham Tran
Shelley Wright

Astrophysics
Ozlem Celik
Eugene Ch
Christian Howard
F. Elliott Koch
Weichung Ooi

Theoretical Biophysics
Rouzbeh Ghafouri

Experimental Biophysics
Edwin Lee

Theoretical Condensed Matter
Ivailo Dimov
Rouzbeh Gerami
Pallab Goswami
Xun Jia*
Wei-Feng Tsai
Karim Wahba

Experimental Condensed Matter
Alexander Bass
Juan Escobar

Experimental High Energy
Pedram Boghrat

Theoretical Plasma
Andreas Liebscher
Gabriel Plunk
Meixuan Shi
Eric Wang

Experimental Plasma
David Pace
Anne White

Theoretical Elementary Particles
Anthony Hall
James Hansen
Henrik Johansson*
Darya Krym
Kalliopi Petraki
Akhil Shah

awards

The E.Lee Kinsey Senior Award, recognizing the outstanding physics senior, went to Nickolas McColl.

The Geoffrey Hilton Award, recognizing the outstanding Astrophysics senior, was shared this year by Tiffany Meshkat and Marissa Rosenberg.

The Rudnick-Abelmann Scholarship for 2008-09 were awarded to Eric Hemsing and Lea Fredrickson

The Rudnick-Abelmann Scholarship for 2009-10 were awarded to Breann Sitarsky and Oswaldo Alvarenga

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