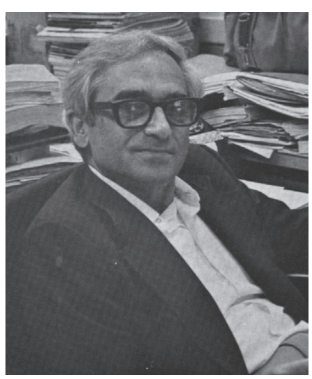
# Quantum Leap

University of South Carolina
Department of Physics and Astronomy





## Gone, But Leaving an Everlasting Impact

Edward Clarence Lerner was born and raised in Brooklyn, N.Y.

After graduation from high school, he attended the Massachusetts Institute of Technology. Following graduation he was commissioned in the United States Navy as a reserve officer. He served in the Pacific Theatre at the end of the war.

Upon his release from active duty, Lerner entered graduate school at MIT and obtained his Ph.D. degree in 1952. He worked in the Lincoln Laboratory for several years and joined the physics faculty at USC in 1957.

Lerner was instrumental in structuring both the undergraduate and graduate programs and taught many of the courses himself. He was a superb teacher and an excellent mentor for junior faculty. He was selected as the first Carolina Endowed Professor of Physics and Astronomy, but declined the honor and retired shortly thereafter.

He will be remembered as one who made many contributions to the teaching program and as the one who attracted Yakir Aharonov to USC in 1965 to build perhaps the top foundations of quantum theory groups in the world. Since that time Aharonov has won many honors, culminating in the 2010 National Medal of Science.

Professor Lerner's impact on the Department of Physics and Astronomy was seminal and will have lasting influence long into the future.


UNIVERSITY OF SOUTH CAROLINA
College of Arts and Sciences

# New faculty

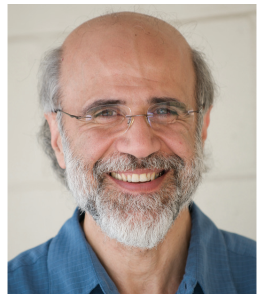
Matthias Schindler

Dr. Matthias Schindler joined the Department of Physics and Astronomy in January 2011. He received his doctoral degree in physics from the University of Mainz, Germany, in 2007. His thesis was on higher-order calculations in baryon chiral perturbation theory. Before joining USC, Matthias held research positions at Ohio University and George Washington University, where he mainly worked on theoretical approaches to describing two- and three-nucleon systems.

Matthias says, “Nuclei consisting of only two, three, or a few protons and neutrons are very interesting objects. While we believe that the theory of quantum chromodynamics correctly describes the strong interaction, we do not yet know how quarks and gluons conspire in QCD to form the known nuclei. Starting from fundamental concepts, I am researching how to systematically describe few-nucleon systems. These are the natural starting point before considering more complex nuclei, and they played a major role in the formation of elements after the big bang.

“A good understanding of these light nuclei is also of interest to particle physics. In addition to high-energy experiments such as those performed at the LHC, high-precision measurements have become a valuable tool in searching for new physics. These experiments often involve light nuclei. My current focus is on the study of parity violation in nucleon interactions. There is an ongoing experimental effort to observe parity violation in neutron reactions at Oak Ridge National Laboratory, and I am looking forward to close collaborations with the fundamental neutron physics group at Oak Ridge. And I am of course excited about working with students and my colleagues here at USC.”

# A Message from the Chair



Chaden Djalali

**Dear Friends and Alumni,**

Greetings from the Department of Physics and Astronomy at the University of South Carolina! I truly appreciate the opportunity that the newsletter gives me to drop you a note about the state of the department. In spite of the global economic downturn that has affected everyone, the department has continued to make progress on all fronts thanks to our enthusiastic students, dedicated staff and committed faculty going beyond the call of duty, and engaged alumni and friends. As I had mentioned in the previous newsletter, the whole department was bracing itself for an additional 5 percent permanent cut, and everyone worked very hard to prepare for such a cut with a plan that would minimize the impact on teaching and research. Fortunately, early last spring, we got the good news that the cut would not go into effect and that we could, with cautious optimism, consider the worst behind us. Let’s hope that this is indeed the case.

The research activity in the department is as strong as ever, and extramural funding has increased in these tough economic times, which is a true credit to the quality of scholarship carried out in the department. The undergraduate program has continued to increase in size, and all the introductory physics courses for science majors are full. Undeterred by the financial situation, our faculty and students continue to excel. A few of their many achievements deserve special mention. Professor Thomas Crawford was awarded the Micheal J. Mungo Undergraduate Teaching Award, and Professor Yaroslaw Bazaliy was chosen as one of the 2011 USC Rising Stars. Two of our undergraduate students have won prestigious national fellowships: Reggie Bain and Jim Talbert were named Barry M. Goldwater Scholars for 2011. Congratulations to all of them!

This year, we had a retirement and a departure among our staff members. After many years of outstanding service, Robert Sproul retired this past June. We are all happy that he has accepted to continue with the department as “factotum emeritus.” Mary Papp, who for more than 10 years took care of all our travel authorizations and reimbursements, among many other things, left us in June to move to the upstate. We all miss her and wish her well in her future endeavors.

Please join me in welcoming several new people to our department. Professor Matthias Schindler joined us in January 2011 as an assistant professor in theoretical nuclear physics and fundamental symmetries. In July 2011, James Clawson and Evelyn Wong joined us as our new laboratory manager and our new administrative assistant, respectively. This summer, we welcomed eight new graduate students from six countries.

We recently heard about the passing of Distinguished Professor Emeritus Ed Lerner, who played a major role in building up our department. He will be missed as a colleague, an outstanding scholar and a passionate supporter of the department.

Before closing, I want to mention that this is my last message as chair of the department. I want to thank the many members of the department who have helped make my tenure as chair enjoyable and manageable. I want to stress that our administrative staff play an absolutely essential role in keeping things going. Without their help, I would never have survived all these years!

As always, I strongly encourage you to keep in touch. If you are interested in engaging in any aspect of departmental life, whether keeping up to date or making contributions to our many activities in teaching, scholarship, or public outreach, don't hesitate to contact us!

Thank you to all!

# Staff News 2011

It's hard to believe another year has passed! Although there may be a few random boxes hiding in corners, we finally finished settling back into Jones PSC after the asbestos abatement project. We also experienced some challenging times with multiple budget cuts. No matter the situation, the staff has continued to work as a team to assist in keeping the department running smoothly. Dee Brown (graduate program coordinator), Ray Edmonds (part-time technician), Beth Powell (administrative coordinator), and Lisa Saxon (business manager) have continued staying as busy as ever in their positions, but the summer definitely brought about several changes.

Emotions were mixed when Mary Papp (administrative assistant) announced that June 3 would be her last day with us because her husband, Rick, had accepted a position with a charter flight company based in Charlotte. We were excited for both of them for the opportunity it presented, but we were also very sad since it meant Mary would leave us to move to Rock Hill (their families live there). At least it's not too far up the road, but Mary, Rick and their son, Will, are greatly missed!

James Clawson

After more than 32 years of service, Robert Sproul (laboratory manager) retired on June 30. Although this was something that we knew was coming, we also knew we were in complete denial of the actual occurrence. If this had been a typical retirement, the department would probably have had to close. Thank goodness Robert was willing to be hired back as a part-time employee! His knowledge and experience is invaluable. While we would love having Robert continue full time, we are happy he is getting to enjoy a "partial" retirement when we're not keeping him too busy.

On July 1, James Clawson joined us as the new laboratory manager. He received his B.S. and M.S. degrees in physics from Francis Marion and Georgia Tech, respectively, and an M.S. degree in mechanical engineering from USC. James and his wife, Staci, have a one-year-old son, Daniel.

Evelyn Wong joined the department on July 5 as our new administrative assistant. She graduated from USC with a degree in studio arts and is a freelance artist. Evelyn is the proud mother of a furry child (cat), Stormy.

We're very happy to have James and Evelyn join our department! They are both great additions to our team.

That's all of our news for now. We hope everyone reading our newsletter is doing well and look forward to receiving updates from all of you.

Evelyn Wong

Reginald Bain and Jim Talbert Jr.

# Two Undergraduates Chosen for Prestigious Goldwater Scholarships

Two undergraduates in the department, Reggie Bain and Jim Talbert, were awarded Barry M. Goldwater Scholarships this year. These prestigious awards are awarded nationally to about 275 undergraduates majoring in the natural sciences, mathematics and engineering for outstanding work in undergraduate research and course work. Bain and Talbert are among roughly 35 physics majors nationally to receive the award this year.

Bain is double majoring in physics and mathematics. He works with Milind Purohit on experimental high-energy physics research. As part of the CERN ATLAS project, they study topics such as supersymmetry and ATLAS detector physics. Talbert is working on the South Carolina Honors College's Baccalaureus Artium et Scientae major focusing in physics and the philosophy of science/physics. He works with Fred Myhrer in nuclear/particle theory and is now focusing on neutrino oscillation. He is also interested in philosophical and historical research in physics. Both students are seniors in the Class of 2012 and plan to pursue Ph.D.'s in physics. Reggie hopes to contribute to supersymmetry and string theory research, while Jim intends on continuing in electroweak phenomenology and BSM topics, like neutrino oscillation.

Bain and Talbert have also collaborated with Jeff Wilson, the South Carolina Honors College, and the Center for Science Education to develop their science outreach initiative Carolina Science Outreach. This organization has received two grants for development. They most recently taught physics and math to sixth graders at the Center for Science Education's annual Summer Science Institute for middle school students and teachers.

Both Bain and Talbert are Carolina Scholars, Palmetto Fellows, Magellan Scholars, Carolina Leadership Scholars and members of Phi Beta Kappa. Bain is a member of the Pi Mu Epsilon Mathematics Honor Society. He recently won the 2011 College of Arts and Sciences Rising Senior Award in Physics and the 2011 Polston Family Scholarship for Excellence in Mathematics. Bain also delivered a poster presentation at the August 2011 ATLAS physics workshop. Talbert contributes to numerous campus groups, including the Religion and Science Initiative and the Carolina Judicial Council. In July 2011 he participated in an intensive lecture series, "The Nature of Scientific Evidence," hosted by the Vienna Circle in Vienna, Austria.

## Updates from the Director of Graduate Studies

Our graduate program remains strong and presently totals 39 students from 14 countries. This year, we welcomed eight new students from six countries (three from the United States, one from China, one from Colombia, one from France, one from India and one from Iran). One of our new students, Gary Hollis, has been awarded a prestigious Presidential Doctoral Fellowship. We are pleased about the strength and diversity of our program.

Our students continue to excel. Hongyue Duyang was selected for the Graduate Student Research Award, and Andres Sanabria for the Graduate Student Teaching Award. Manlai Liang and Shu Yan won graduate school travel grants to attend the American Physical Society Meeting. Within the last year our department awarded a total of nine degrees. Our MS and Ph.D. graduates continue to find positions in private industry, government and universities throughout the region and country.

The Department of Physics and Astronomy is continuously working to improve the quality of the program and better fulfill the needs of our students. We look forward to another productive and prosperous year ahead.

### Congratulations to these graduates:

#### Doctoral

Alejandro Ferrero
Baowei Liu
Ryan White

#### Master of Science

Tareif Alkhatib
Ziyad Alrowaili
Rebecca Bowers
Zhelin Sun
Huaizhou Zhang
Dong Xue

## News from the Director of Undergraduate Studies

The undergraduate program has continued to increase in size. Our introductory classes for majors are almost completely full in both fall and spring semesters. This increase is also starting to trickle into the intermediate courses. When the final count is in for 2010-2011, we expect to have about 10 graduates for the academic year- matching the numbers from the two previous years.

Along with the increase in enrollment, we are seeing greater demand for our 500-level lab courses. Students have been requesting greater variety as well. In response to this, Professors Thomas Crawford and Scott Crittenden have been working to transform several of our courses (Optics, Theory and Applications; Condensed Matter; and Biophysics) into a modular inquiry-based format, allowing students to build a program tailored to their own interests and abilities. This allows us to increase choice while keeping the teaching commitment manageable.

Two of our physics students, Reginald Bain and Jim Talbert Jr., were named 2011 Barry M. Goldwater Scholars. The Goldwater Scholarship is awarded nationally to sophomores and juniors pursuing bachelor's degrees in natural sciences, mathematics, or engineering and intending to pursue a career in research and/or college-level teaching: virtually all the scholars intend to obtain a Ph.D. in their respective fields. The university, as well as all other institutions of higher education, may only nominate four students for this award. A link to a longer write-up on this award can be found on the Department of Physics and Astronomy home page at www.physics.sc.edu. Two of our most energetic undergraduates, Bain and Talbert are also co-founders of the Carolina Science Outreach program, which they formed to disseminate scientific knowledge throughout South Carolina. They have road shows and presentations about recent science topics that are tailored for the specific audience. Details of this program can be found at www.carolinascienceoutreach.org.

There were several award winners from physics at the spring 2011 awards ceremony. Reginald Alexander Bain won the College of Arts and Sciences Rising Senior Award, Gary D. Hollis was awarded the Nina and Frank Avignone Fellows Fund, and Phillip Steven Keck won the Rudy Jones Physics Award. Reginald Bain also won the Polston Family Mathematics Scholarship.

## Particle Theory Group

**Faculty: Brett Altschul, Vladimire Gudkov, Pawel Mazur and Mathias Shindler**

In January 2011, a new faculty member was added to the Particle Theory Group. Professor Matthias Schindler joins Professors Pawel Mazur, Vladimir Gudkov and Brett Altschul. Schindler earned his Ph.D. in 2007 at the Johannes Gutenberg University in Mainz, Germany, and after finishing his doctorate, he was a post-doctoral research associate at Ohio University and then George Washington University in Washington, D.C.

Professor Schindler is an expert on effective field theories for hadrons, especially their use in interpreting experimental tests of fundamental symmetries, such as parity (P), charge conjugation (C) and time reversal (T). He added this expertise to a Particle Theory Group for which fundamental symmetries is already one of the most important areas of research and collaboration. Professor Gudkov is also working on interpreting tests of P and T in systems with small numbers of protons and neutrons.

While P violation in nucelons and nuclei is relatively straightforward to observe (P violation was first observed in the beta decay of Co-60), T violation has not been observed in such systems. T violation does exist in the stanadard model of particle physics, and it has been observed in the oscillations of neutral mesons, but the expected size of T violation in nucleon systems is to too small to be measured with current technology. That means that any experimental evidence of nucleonic T violation would be a sure indication of new physics beyond the standard model and thus a discovery of paramount importance. In fact, some form of T violation beyond the standard model is almost certain to exist since it is needed to explain the predominance of matter over antimatter in our universe.

This is actually an extremely exciting time for precision symmetry studies using nucleons, because experiments at the Spallation Neutron Source (SNS), located at the Oak Ridge National Laboratory in Oak Ridge, Tenn., are expected to provide a tremendous amount of new and interesting data in coming years. Fundamental neutron physics is also the main focus of Prof. Gudkov's research, and USC has developed a very strong relationship with Oak Ridge. The SNS is the most powerful neutron source in the world. It produces neutrons by colliding an accelerated beam of protons with target nuclei. Each collision produces a spray of neutrons, and the neutrons are split into up to 18 beams, which will be used for different types of experiments. Some of the beam lines are complete, with operational instruments installed, while some are still in various stages of preparation. Of particular interest is the SNS's Fundamental Neutron Physics Beam Line (FNPB), which started operating in 2008. While most of the beam lines use neutrons as probes for studying other materials, the focus of the PNPB is on the neutrons themselves.

Gudkov, Schindler and postdoctoral research associate Young-Ho Song are all working on developing improved descriptions of P and T violation in nucleon systems. One powerful technique is the use of low-energy effective field theory (EFT). The EFT framework offers a systematic way of describing all the possible symmetry-violating interactions that could occur; all possible low-energy observables are parameterized in terms of a fairly small number of numerical constants. Those constants must be fixed with data from experiments, but once that is done, the low-energy behavior of the theory is completely constrained. Moreover, even if the existing data is not precise enough to determine all of the numerical constants accurately, the EFT method may provide insights into how new observable effects might be uncovered.

Even more exotic forms of symmetry breaking are also possible, and Professor Altschul works on such unusual forms of new physics. One possibility that he has been looking at with Alejandro Ferrero, who earned a Ph.D. in May, is that the "constants" of nature, such as the electron charge, the proton mass and the strength of the weak interaction that is responsible for the decay of neutrons and many other particles, may actually be changing with time.

Altschul has also looked recently at the possibility of changes to particle quantum statistics. So far as is known, all particles with integer spin are bosons, with no limit on how many of them may occupy the same state. However, particles with half integer spin are fermions, and no more than one fermion may occupy a single quantum state. Photons have spin 1 and should therefore be bosons, and Altschul showed that if they indeed were not purely bosonic, that would have drastic effects on the propagation of electromagnetic waves through the solar wind. This result provided a much improved experimental constraint on deviations for conventional photon statistics.

Professor Mazur continues to work on the physics of black holes. He is currently working with a Ph.D. student, Andres Sanabria, studying the unusual behavior that can be seen in particles orbiting black holes. For small orbits, general relativistic effects become quite important, and relativistically modified orbits can differ from conventional ones in several important ways. Orbiting satellites may zoom in and out, tracing out novel patterns, and the orbits may also be affected by the gravitomagnetic field generated by a rotating black hole.



Condensed Matter Group

## Condensed Matter Theory at Nano-scale

**Faculty: Yuriy Pershin and Yaroslaw Bazaliy**

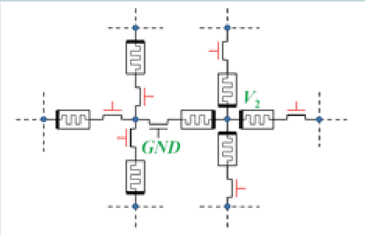
The groups of Yuri Pershin and Yaroslaw Bazaliy are involved in the theoretical investigations of the nanoscale condensed matter systems.

The nanomagnetism group of Bazaliy studies the properties of nano-size magnetic particles. Particles of this type eventually will be used for the next generations of magnetic memory, and it is important to develop a good understanding of their physical properties beforehand.

An important property of any memory is its writing speed. In the last year we have investigated the speed of switching of the nanoparticle's magnetic moments under the action of the external magnetic field. This process is often studied theoretically with an assumption that the field is turned on instantaneously. Of course, in real life it always takes some time to change the field, and minimizing this time may be a difficult technological problem. By doing numeric experiments, our collaborator from the NVE corporation, Andrzej Stankiewicz, found a surprising result: Turning the field on instantaneously actually does not provide the best switching speed. The dependence of the magnetic moment switching time on the field switching time is non-monotonous and has a minimum at a particular (optimal) field switching time. In our work published in Applied Physics Letters (2011) we have explained the physics behind this counterintuitive phenomenon and derived a simple expression for the optimal field switching time. Our result will be useful for the engineers developing magnetic memory devices.

see Condensed Matter, pg. 6

## Condensed Matter continued from pg. 5




A figure showing key components of memristive processor

For example, it shows that there is no need or benefit in designing magnetic writing heads with the field switching time shorter than the optimal value. The paper created an interest in the community, and we have several outside researchers contacting us to discuss the results.

During the academic year 2010-2011 two students defended their master's thesis in the group. One of them, Zhelin Sun, together with another graduate student, Shu Yan, worked on the problem of magnetic dynamics induced by electric current. The so-called spin-transfer effect provides a way of controlling the magnetic moment of nanoparticles by electric current. In our work we have considered a problem of magnetic switching in the presence of this effect. Normally magnetic switching of a moment with a uniaxial anisotropy is described by a diagram called a Stoner-Wohlfarth astroid. The modification of this diagram in the presence of spin-transfer was considered in the recent literature, though approximately. We have found a way to write an exact theory of the astroid modification. Such a progress allowed us to find new features that were missed by the previous researchers. This work is currently prepared for publication. Spin-transfer induced dynamics is the major topic of research in the group. One other paper in this field is currently in press, and yet another one is submitted.

During the year we were fortunate to have a half-dozen visitors, including international ones, who had contributed to making the departmental condensed matter seminar program interesting and vibrant. Those seminars where theorists and experimentalists come together to discuss current developments in the field also benefited from the Internet-based seminar program conducted by the group (see another article in this issue).

Professor Yuriy Pershin and his team are using numerical and analytical techniques to study electronic and ionic transport at nanoscale. The general goal of this research is to understand physical phenomena that can be potentially used in future electronic devices. Many of their studies require significant computational resources. Recently, Pershin has established an Academic Partnership Program with NVIDIA Corporation, the leading manufacturer of GPU computing hardware. Ibrahim Savran, a graduate student in USC's Department of Computer Science and Engineering, has written a parallel version of spintronics simulations code and has achieved more than 200X speed-up utilizing the last generation of Tesla GPU boards received from NVIDIA. The results of these numerical calculations will complement an analytical theory of spin relaxation in confined geometries being developed in collaboration with Professor V. Slipko from Ukraine.

Memory effects in nanoscale structures are topics of great current importance and interest since they can be employed in the next generation of nonvolatile high-density memory. Together with Professor Di Ventra from the University of California San Diego, Yuriy Pershin has designed a massively parallel memristive processor and has demonstrated that it is extremely efficient in solving certain optimization problems. In particular, the memristive processor solves the maze problem (in which, given an entrance point, one has to find the exit via an intricate succession of paths) faster than any existing algorithm. Mazes — sometimes also called labyrinths — have been known since ancient times, the oldest presumably being the one created by Daedalus in Crete, and are used as prototype models in graph theory, topology, robotics, traffic optimization, psychology and many other areas of science and technology. This work has attracted a lot of attention and was recently highlighted in Science Magazine.



# Global Reach of a Local Seminar

Yaroslaw Bazaliy
USC, Department of Physics and Astronomy

During the last academic year the departmental condensed matter seminar employed a new mode of operation — Internet seminars by remote speakers from all over the world. This experiment was accepted with enthusiasm by both experimentalists and theorists. It is interesting to put this new approach in the context of the communication patterns that were followed by the physicists over the last 100 years of history.

In the early 20th century there were few practicing researchers, and most of them knew each other from personal contacts. Exchange of letters between the now legendary physicists was a common practice. Consider, for example, a well-known case. Young Satyendra Bose informed Albert Einstein about his work on what is presently known as Bose-Einstein condensation by writing a letter from India to Germany. At the beginning of the 20th century a paper letter did not travel very fast (and now, at the beginning of the 21st century, this speed is still about the same). The delay was, however, not really important, as long as the delivery time did not dramatically exceed the time it took to think about the physics content of the letter. Whatever can be said about the effectiveness of postal communication then and now, the personal contacts created by such a correspondence were precious for the development of physics, forming a worldwide network of researchers and producing a global flow of ideas.

With a rapid development of physics, especially after World War II, the practice of personal letters faded. One can argue that the reason for that was simply a growing number of people working on similar problems. Instead of having direct contacts with hundreds of colleagues, it was more practical to read their articles published in scientific journals. The change of the communication mode was natural. For a while, personal contacts between physicists continued to flourish at the scientific conferences. But as the conferences grew in the number of attendees, the chances of having extensive discussion were diminishing. The advent of computer presentations and PowerPoint slide culture pushed the process even further. A physics conference talk is often evolving into a form of a short advertising session for the results, which ultimately should be understood by studying the journal papers. Thus, in a paradoxical way, computer communication technologies contributed to the diminishing of direct personal contact between researchers from different scientific institutions. Undoubtedly, the proliferation of email and, especially, the establishment of the physics archive server in 1991 (www.arXiv.org) dramatically increased the speed of manuscript exchange. This, service, however, did not become a source of many new collaborations or real-world contacts between physicists. The archive was rather used by the already formed scientific groups to compete with each other and establish priorities of their research papers. While this function was very useful and important, it had little to do with personal communications.

Whether the information technology age will be able to help scientists to reestablish the type of informal contacts characteristic for the researchers of the "golden age" of physics remains largely an open question. Starting in 2010, the condensed matter physics group at our department started a practice which may be viewed as a step in this direction. We have developed a system of organizing Internet-based seminars with the speakers from all parts of the world where a network with sufficiently good bandwidth is available. As such, the teleconferences are not a new phenomenon. What is probably new in our days is the possibility of organizing a teleconference with very modest means in a do-it-yourself fashion. By sacrificing a little in the quality of video information, one is able to remove one of the most important roadblocks on the way to Internet seminars: the necessity for the speaker to make special arrangements for his/her talk. At present, there are free software packages and services allowing one to give a seminar out of his/her office after a very short training session. The audience listens to the presentation in a seminar room equipped with nothing more than a pair of speakers and a computer projector. A few radio microphones (normally used by Karaoke enthusiasts) enable everyone to ask questions during the talk. The overall performance of the system can be rated as satisfactory most of the time.

Up till now we had six presentations given by remote speakers. This constituted 30 percent of all seminar talks. First of all, the online seminars allowed us to listen to people who we normally would not be able to invite due to funding constraints. Second, we essentially had an opportunity to get a speaker on demand according to the current interest of the faculty. For example, we had a case where a certain paper, fresh in print, was discussed internally at a journal club meeting. The next week we invited the author of the paper to give an Internet talk. This was a great opportunity to discuss the interesting points of the work with the author to the satisfaction of the audience.

Such interactivity of remote seminars is truly a very strong point. It gives an opportunity to contact the authors of just-published preprints and papers directly and discuss precisely those issues that interest the audience on our side. This capacity moves us in the direction of developing a more personalized and comprehensive type of contact between the physicists. In science, written communication is the most developed mode of information exchange. But even in the best-case scenario, it fails to convey all information about the ongoing research process. In reality, when first results are published in the form of short letters, it becomes even more difficult to understand and appreciate the new ideas. A personalized, on-demand presentation can become a crucial help for the researchers interested in a particular recent development.

The practice of remote seminars at USC is new. It is hard to say exactly how far will we go before its potential will be exhausted and what other interesting forms of scientific Internet communications will be discovered in the near future. We have made just the first step. It will not solve all the problems or eliminate the need of real personal communication, travel and work in the same office with your collaborator. After all, Bose eventually traveled to Germany to meet Einstein.…

## Particle Astrophysics Group

**Faculty: Frank Avignone, Richard Creswick, Horacio Farach and Carl Rosenfeld; Graduate Students: Nicholas Chott, Leila Mizouni and Seth Newman: Recent Ph.D. Graduates: George S. King (2007), Todd Hossbach (2009) and Carlos Martinez (2009)**

Particle astrophysics focuses on phenomena in astrophysics and cosmology associated with the properties of elementary particles ranging from neutrinos to weakly interacting massive particles (WIMPS), hypothesized as the cold dark matter (CDM). The USC group was very early in the field when it made the first sensitive terrestrial CDM search. CDM is needed to explain the dynamics of galaxies and important features of cosmological models used to explain the evolution of the universe. The gravitational effects of CDM on the velocity distribution of stars in spiral galaxies is well established. It was motivated by the discovery in 1933 by Fritz Zwicky that far more mass is needed to explain the dynamics of globular clusters than appears in stars and dust. In 1985, the USC group, inspired by the astrophysics group at Max Planck Institute in Munich, led the first terrestrial search for the CDM in the Homestake goldmine in Lead, S.D., with a unique detector developed with the Pacific Northwest National Laboratory (PNNL). This collaboration remains active today. The first experiment was able to eliminate heavy Dirac Neutrinos as the major component of the CDM. These searches have now become popular throughout the world, with vast improvements in detector technology.

The USC group has also led several searches for elementary particles called axions emitted by the sun. Axions result in the theory by Roberto Peccei and Helen Quinn that explains why the strong interactions, described by quantum chromodynamics, do not violate charge-parity (C-P) symmetry. The predicted violation would lead to an electric dipole moment of the neutron many orders of magnitude larger than the experimental bound. The USC-lead axion search experiment was based on an analysis developed at USC by an international collaboration led by Richard Creswick. It uses the coherent Bragg conversion of axions to photons in single crystals when the line from the detector to the solar core satisfies a Bragg condition. This technique has been and is being used by other groups worldwide.

The USC group now concentrates on two searches for the exotic zero-neutrino nuclear double-beta decay ($0\nu\beta\beta$ – decay), which is only possible if neutrinos have mass and are their own antiparticles (Majorana particles). The $0\nu\beta\beta$ – decay mode also violates the law of lepton-number conservation. Neutrino oscillation experiments imply that neutrinos may well have enough mass to allow this exotic decay to be measurable, but they can only measure mass differences. The measurement of the decay rate of $0\nu\beta\beta$ – decay would determine the absolute masses of all three neutrino-mass eigenstates.

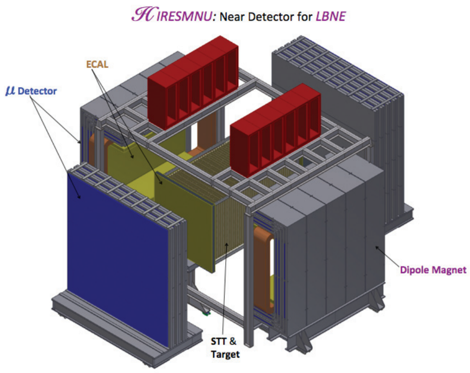
The USC group was heavily involved in the CUORICINO double-beta decay experiment in the Gran Sasso laboratory in Assergi, Italy, from the very beginning until it was discontinued in July 2008. It set a lower limit on the half-life for the $0\nu\beta\beta$ – decay of $^{130}$Te of $2.5 \times 10^{24}$y. CUORICINO was an array of ~42 kg of $TeO_2$ cryogenic detectors operating at ~0.008 K. The current effort, however, is in the construction of a 760-kg version called CUORE. The group's main responsibility is the production of the electronic system led by Carl Rosenfeld. The group has the U.S. leadership role in the construction and operation of the first tower of CUORE (CUORE-Zero) that will operate in 2011 in the CUORICINO cryostat.

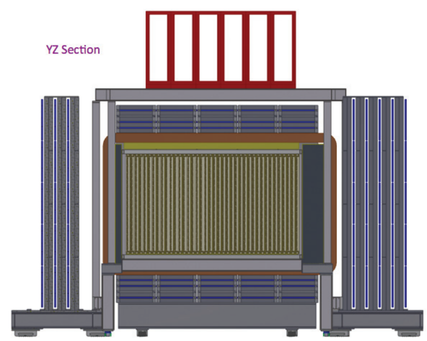
see Particle Astrophysics, pg. 8

# Neutrino Group

## HIRESMNU as the reference Near-Detector for LBNE

The Long Baseline Neutrino Experiment (LBNE) collaboration has chosen the HIRESMNU (see Quantum Leap '09) as the reference Near-Detector (ND). The detector, HIRESMNU, comprises a high-resolution, low-density (0.1 gm/cm^3) straw-tube tracker (STT) surrounded by a fine-grained electromagnetic-calorimeter (ECAL) and embedded within a 0.4 T dipole magnetic field; muon-detectors instrument the magnet and two stations downstream of the STT. Professors Sanjib Mishra, Roberto Petti and Carl Rosenfeld proposed the HIRESMNU idea as a generation advance in the investigation of neutrino oscillations and masses and in precision neutrino-interactions made possible by the unprecedented neutrino fluxes foreseen in the LBNE era. An engineering schematic of HIRESMNU is shown below. Professor Jeff Wilson is joining the LBNE effort. Professors Mishra and Petti are leading the ND physics group in the LBNE collaboration. Postdoctoral fellows Dr. Xinchun Tian and Brian Mercurio and graduate students Hongyue Duyang and Libo Jiang are participating in the LBNE-ND related research. Graduate student Chris Kullenberg and undergraduates Luis Suarez and Kayla Hasbrouck are working with Professor Mishra to quantitate the precision on the absolute neutrino flux at LBNE.






## MINOS and NOvA Projects

The MINOS experiment continues to conduct neutrino oscillation measurements with ever higher precision. MINOS is the first generation of such experiments. Recently, the MINOS experiment, dubbed MINOS+, was granted a Stage I approval to continue running with modest upgrades during the NOvA operation. Part of the upgrade is a small, but charming, measurement of neutrino-speed proposed by Professors Mishra and Rosenfeld.

NOvA, a second-generation oscillation experiment, is under construction. NOvA is scheduled to begin operation in 2014. The Carolina group's responsibilities on NOvA include Monte Carlo simulation, beam studies and data-acquisition system. Mishra, Rosenfeld, Wilson, Tian and Mercurio work on NOvA.

## Particle Astrophysics continued from pg. 7

The USC group also played a key role in establishing the MAJORANA $^{76}$Ge double-beta decay project, which is a research and development project to establish the feasibility of building and operating a one-ton experiment in the U.S. Deep Underground Science Laboratory (DUSL). The principal technology being used is a vastly improved version of the IGEX experiment, also lead by the USC group in the 1990s. The one-ton experiment is further in the future. It will depend on the level of success of the Demonstrator project. All of these activities are supported by major grants from the National Science Foundation.

## Oscillation Sensitivity in a 200 kT Water Cerenkov (WC) LBNE Detector

A 200 kT WC is the leading candidate for the LBNE far-detector. Professors Mishra and Rosenfeld, graduate student Duyang, and undergraduates Tyler Alion and Andrew Svenson are evaluating the WC's sensitivity to electron-neutrino appearance. Their preliminary analysis reveals that the LBNE-WC's sensitivity is 50-70 percent higher than the earlier estimates.

## Some Physics Results

Mishra, Petti, graduate students Jae Kim and Chris Kullenberg, and undergraduate students Suarez and Hasbrouck continue their analyses of the voluminous data on neutrino-nucleus interactions compiled by the NOMAD experiment at CERN. Last year graduate students Jiajie Ling and Jae Kim defended their Ph.D. theses on the MINOS electron-neutrino appearance and on the measurement of the most precise analysis of quasi-elastic neutrino scattering, respectively, under Professor Mishra's supervision. Recent analysis by Kullenberg and Mishra have resulted in the most precise measurement of coherent neutral-pion production in the neutrino interactions. The work has yielded another important result: the most stringent bound on a novel phenomenon called Anomaly-mediated Neutrino-Photon interaction (ANP). These results directly impact the neutrino-oscillation search in NOvA and LBNE experiments. Professor Petti, with colleagues from JINR-Dubna, has completed a precision study of neutrino-induced charm-production and strange sea determination using NOMAD data.

## High-Energy Experimental Group

**Faculty: Sanjib Mishra, Roberto Petti, Milind Purohit, Carl Rosenfeld and Jeff Wilson**

"Will 2011 be the year of the Higgs?" This was the big question at the ATLAS meeting attended by undergraduate Reggie Bain, graduate student Anton Kravchenko and Professor Milind Purohit at Boston University's Photonics Lab. The answer may not be known until the end of the year. The Higgs particle, in what is called the "Standard Model" of particle physics, gives mass to everything around us. Finding it is central to completing our basic picture of what the universe is made of. On August 15, 2011, the CERN laboratory issued a press release about the search for the Higgs. There are hints of something in the "low mass region" that are seen by both ATLAS as well as the other general purpose detector, CMS. However, until both of these see a significant peak in one or more clean decay channels, we cannot be sure. We have data in hand now that may answer the question definitively. Will 2011 be the year of the Higgs?

# Experimental Condensed Matter and Nanoscale Physics Groups

**Faculty: Thomas Crawford, Scott Crittenden, Timir Datta, Milind Kunchur and Richard Webb**

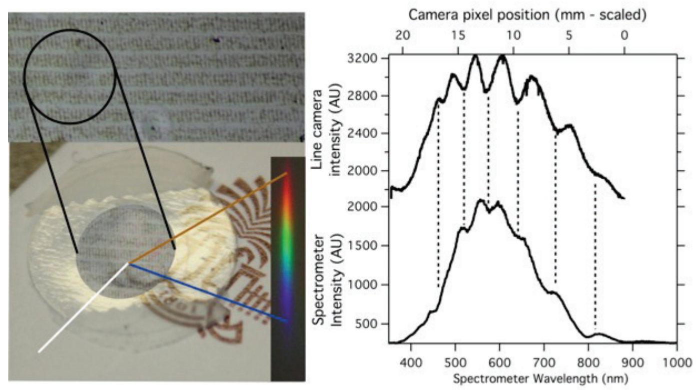
## A shot in the arm for USC condensed matter physics and nanoscience:

This summer, USC physics and astronomy was given approval by the College of Arts and Sciences to search for our five-year-vacant tenure track experimentalist position in functional nanomaterials. Our faculty members strongly believe this position will give us critical mass to pursue "center" funding for the team-based effort already underway within the group. With strong successes obtaining single PI funding and exciting projects underway, the condensed matter and nanoelectronics faculty are excited about the research opportunities available for graduate students, postdoctoral fellows and even undergraduates to learn the crafts and skills of experimental condensed matter physics.

## Playing with nanomagnets

**Professor Thomas Crawford**'s laboratory for picoscale metrology and nanomagnetics continues its focus on a horizon that ranges from basic to applied physics research. 2010-11 has seen exciting personnel changes as group members depart for the real world, obtaining jobs in a very difficult economy. Research professor **Dr. Samir Garzon** joined Hitachi Global Storage Technologies (HGST) in early 2010, while postdoctoral scholar Dr. Irina Roof took a position with Zeus Inc. and undergraduate **Jason Henderson** obtained his bachelor's degree and joined Milliken Research Corporation in 2011.

Ph.D candidate **Longfei Ye** continues to develop our ultrafast magnetodynamics project studying spin torque dynamics in nanomagnets while also optimizing our ability to make multilayer nanomagnet devices here at USC. Ye is currently employing opposite polarity pulses and how the polarity and timing affect the resulting dynamics. Research continues in collaboration with the **Crittenden** group studying the properties of self-assembled monolayers such as short chains of DNA grown on Au. Such monolayers can be monitored through electrical transport and have potentially very interesting magnetic properties.




A diffraction grating built entirely from nano particles using magnetic-force-directed assembly. Top left: optical image of magnetic nano particles assembled into patterns on disk drive media; bottom left: peeled poly-vinyl-alcohol film containing patterned nano particles demonstrates white-light diffraction; right: optical spectrum of white light measured with nano particle grating (top) and with commercial spectrometer (bottom). We believe this is the first free-standing transmission diffraction grating built entirely from nano particles. (Courtesy: T.M. Crawford)

Finally, the group continues to increase its focus in the area of nanomanufacturing. With NSF funding over the past three years, and a new three-year NSF collaborative award recently recommended for funding, Crawford has developed a strong collaboration with **Thompson Mefford**, a polymer chemist in the materials science department at Clemson. The **Mefford** group specializes in synthesizing magnetic nanomaterials, which can be assembled into larger macroscale patterns using the enormous magnetic field gradients from recorded transitions at the surface of a magnetic recording disk. These fields are written into arbitrary nanoscale patterns using a magnetic recording head, and after assembling the nanoparticles, the disk is coated with a curable polymer. Once cured, the polymer is peeled from the surface, transferring the nanoparticle pattern to a flexible and optically transparent substrate. Calling this technique "pattern transfer nanomanufacturing," **Crawford** has a patent pending on this technology. This summer, new group members **Aneta Netz** (graduate student, physics) and **Brad Terry** (undergraduate, chemistry and biochemistry), building on work done by Henderson before he graduated, have used one of these transparent films containing a thin layer of patterned nanoparticles as a diffraction grating in an optical spectrometer. Netz and Terry compared the nanomanufactured grating spectrum with a commercial spectrometer, demonstrating one potential application for nanomanufacturing. **Crawford** believes this concept and the collaboration with Clemson could help establish the "Carolina Alliance for Nanomanufacturing." **Crawford** extends a warm welcome to any and all visitors who would like to take a tour of our growing facility in the Sumwalt NanoCenter.

see Nanoscale Physics, pg. 10

## Nanoscale Physics continued from pg. 9

### Do bacteria manufacture conductive bionanowires?

Since last year, the **Crittenden** group has grown significantly from three to six full-time researchers: **Dr. Bharat Kumar Kulkarni** (Ph.D., physics, 2009 C.V. Raman Institute, Bangalore, India), **Fiona Oxsher** (graduate student, chemistry), **Jason Giamberardino** (graduate student, physics), **Joe Bonvallet** (graduate student, chemistry), **Chris Pasco** (undergraduate, physics), and **Nestor Peralta** (undergraduate, biology). In addition, there is the customary diffuse group of part-time undergraduates fitting in a little research between course work.

We continue to work with **Professor Linda Shimizu** (chemistry and biochemistry) to measure the conductivity of polydiacetylene nanowires. We are beginning a collaboration with **Professor Richard Long** (biology) to develop a novel microscope that can be taken into the ocean to observe microbial communities in their natural environments. Finally, we are beginning studies of surface mediated transport in low dimensional metals in collaboration with **Crawford** and **Webb**.

**Kulkarni** continues his work on the previous U.S. Army grant to study the conductivity of bionanowires produced by some electrogenic bacteria. In particular, he is investigating the electronic properties of self-assembled monolayers (SAMs) of molecules on gold and silicon surfaces. Also working on the U.S. Army grant is **Bonvallet**, who is focused on solution-phase conductivity measurements. Finally, **Giamberardino** is also working on the grant by studying the electrochemical properties of SAMs and, in conjunction with **Oxsher** and **Peralta**, the solutions of electrogenic bacteria-powered microbial fuel cells (MFCs). **Oxsher** and **Peralta** are conducting experiments to develop a quantitatively predictive theory of MFC power output. In addition, **Oxsher** is working with **Pasco** on a new class of supercapacitor.



**Crittenden** hosted a half-dozen high school students for a week of laboratory experiments producing electricity from bacteria as part of the Nanoscience Summer School organized by **Professor Qian Wang** (chemistry and biochemistry). Last fall semester saw the first offering of the new 500-level biophysics lab course taught in conjunction with **Professor Yaroslaw Bazaliy**. The students successfully built and tested an optical tweezers apparatus and learned a great deal about conducting non-cookbook experiments. Over the summer, physics undergraduate **Graham White** continued working with the system and improved the tweezers' piconewton force calibration technique, which will be used the next time the course is offered. Course development continues, this time via a collaboration between **Crittenden**, **Crawford** and **Altschul**, supported by an internal $8,000 grant from the College of Arts and Sciences, to enhance the 500-level advanced optics laboratory with a series of podcasted lectures and new laboratory experiments.

Finally, **Crittenden** was recently awarded $925,000 over five years from the Department of Defense Multiple University Research Initiative (MURI) Program to study the interactions of biomolecules with nonbiological surfaces through atomic force microscopy. This grant funds the acquisition of a new very high-resolution atomic force microscope while supporting a postdoctoral researcher and a graduate student in the Crittenden group over the next five years.

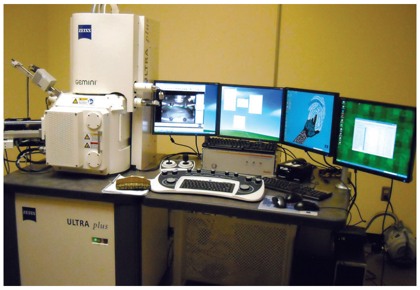
### Gravitation and the macroscopically quantum

**Professor Timir Datta** continues to be active in experimental gravitation and development of gravitational sensors. Yeuncheol is working toward his Ph. D. on the measurement of G, and he has started to obtain experimental data and is preparing his thesis proposal. Huaizhou finished an M.S. project in April 2011, studying the problem of stable magnetic suspensions. The challenge is that Earnshaw's theorem prohibits stability for certain electrostatic or magneto static arrangements, which is removed when induced magnetism and diamagnetism are introduced, e.g. in superconducting levitation. Huaizhou suspended half-kg steel balls under ambient condition using pyrolytic graphite as the diamagnetic stabilizer and strong rare-earth magnets. **Huaizhou** has since moved back to China and has gotten a position at Ericson. **Datta** continues a joint search for new superconducting materials with Mike Osofsky at NRL. Finally, the superconducting magnetic materials work is expected to get a major boost when **Ming Yin** at Benedict College sets up new cryogenic instrumentation, funded through a new $2 million ARO award at Benedict. This summer **Yin** brought four interns to Datta's lab in PSC. Finally, **Raphael Tsu** and **Datta** recently finished a paper on quantum stability of atoms and structures, which **Tsu** presented at the seventh international conference on low dimensional structures and devices (LDSD-2011) in Nuevo Yucatan, Mexico, May 22-27, 2011.

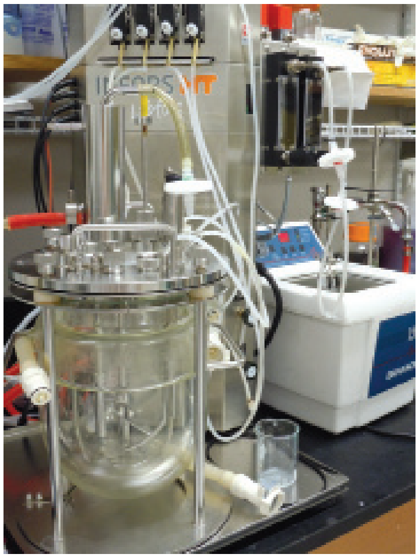
### Supercurrents and superfast acoustics

**Professor Milind Kunchur**'s group research group continues to work in the areas of superconductivity and psychoacoustics. Ongoing experiments probe suppression of superfluid density in superconductors at high current densities and the orientation dependence of the pair breaking current in d-wave superconductors. Currently one graduate student, **Manlai Liang**, and one undergraduate student, **Taylor Jones**, are working in **Kunchur's** group.

### Mechanizing physics at the nanoscale


The Zeiss Ultra plus Field Emission Scanning Electron Microscope in the USC electron microscopy center.

In early January of 2010 **Professor Richard Webb** acquired a Zeiss Ultra plus Field Emission Scanning Electron Microscope that was installed in the USC Electron Microscopy Center. It has 1.0 nm resolution in the SEM mode and 0.8 nm resolution in the STEM mode. It has charge compensation via gas injection, capable of e-beam lithography using Nabity software and installed beam blanker, and sample analysis capability using Genesis Apex2-ED for EBSD and WDS. In 2011 it has been the most used microscope on campus.



Bacterial fermenter used to cultivate eletrogenic bacteria.

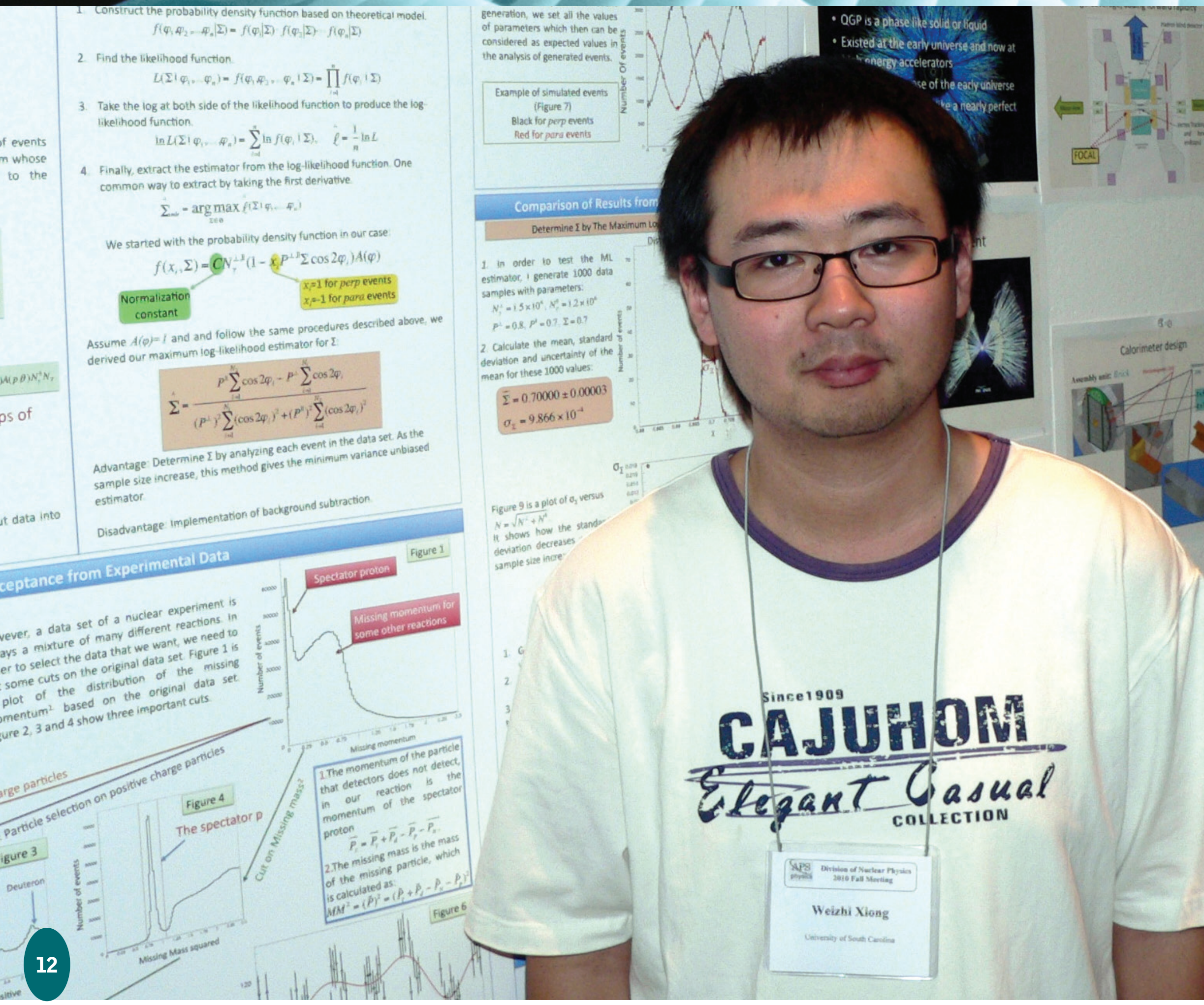
Our NanoElectronics group has recently been developing new structures for the detection of trace amounts of common atmospheric pollutants, such as $NO_2$ using nanostructured materials and a combination of simultaneous measurement techniques. $NO_2$ is responsible for smog and acid rain and typically is present in our atmosphere at levels of ~11 ppb (parts per billion). Using Indium Oxide ($In_2O_3$) thin films, patterned with interdigitated metal fingers, contact pads and an atomic force microscope (AFM), we could simultaneously measure conductance, capacitance and work function changes when the gas was added. For pure 20 ppb $NO_2$, we could measure changes in conductance of 20 percent. Using all three measurements, we could measure these changes in the presence of other combinations of gases (NO, CO, $NH_3$) and clearly identify the contribution due to $NO_2$ only. Our noise-limited detection sensitivity was ~90 ppt (parts per trillion) and was found to be almost two orders of magnitude better than anything previously reported, with possible applications in industrial process flow monitoring. This work was done in collaboration with **Professor Goutam Koley** in electrical engineering.

**Webb** has also been working with **Professor Xiaodong Li**, mechanical engineering, on electrical studies of zinc oxide nanobelts. One-dimensional nanostructure-based devices are envisioned as one of the most promising class of candidates to replace silicon-based devices since they can circumvent the limits of photolithography currently used in silicon technology. Zinc oxide is a good conducting/semiconducting piezoelectric material that has been used in microelectromechanical systems (MEMS) as sensors and actuators. Mechanical damage, which is inevitable in nanodevice fabrication and operation, can lead to malfunction and/or even failure of the entire device. We have just published our study in Nano Letters where, for the first time, we show that by passing a current through our nanobelts we can create an electrical self-healing of damaged devices. We first fabricated pristine nanobelts with no defects, as determined by high resolution transmission electron microscopy (HRTEM), and measured their electrical conductivity as a function of bias voltage. Then using an AFM with a diamond tip, we created mechanical defects by pressing the small tip into the nanobelt (~50 nm thick) with measured forces and leaving an indentation impression in a triangular shape of 216 nm long and 158 nm in width. By continuously measuring the conductivity both before and after the indentation, we were able to monitor the initial decrease of conductivity and subsequent recovery as a function of the indentation force. We discovered three regimes of behavior: elastically deformed, plastically deformed and permanently damaged. All occurred over a range of tip forces from 10 µN to ~100 µN. In the plastically deformed regime, we discovered that the damage was not completely healed and the conductivity did not completely recover to its initial value (as opposed to elastically deformed nanobelts), and using our HRTEM results we developed a model for all these behaviors. We believe that we have shown that we can reproducibly modify the electrical properties of these systems and can tune them to achieve almost any desired conductivity. As a byproduct of these studies, we were able to study the effects of electron beam irradiation on these nanobelts and show that the stiffness (Young's Modulus) increased with increasing electron beam irradiation by as much as 40 percent as compared with the pristine nanobelts.

The **Webb** group is beginning new experiments on graphene, a layer of crystallized carbon one or a few atoms thick, in order to test for the existence of localized states near the edges of the structure. The 2010 Nobel Prize in Physics was awarded to Andre Geim and Konstantin Novoselov for their groundbreaking experiments on the two-dimensional, one-atom-thick flake of ordinary carbon that can have extraordinary electrical and thermal conductivity. Our collaboration is with electrical engineering and Cornell University on the fabrication of this material in both one- and two-atom-thick varieties. After fabrication, we will use e-beam lithography to make excellent electrical contact pads and measure the role of disorder on things like mobility and quantum hall effect as a function of both temperature and magnetic field. It is through these measurements that we hope we can find evidence of the theoretically predicted existence of localized states in this nominally perfect crystal.

In January 2010, **Webb** with **Crawford** developed a new partnership with IBM T.J. Watson Research Center, Yorktown Heights, N.Y., for our work on magnetic tunnel junctions used for information storage. IBM supplies the devices and we perform the measurements, and we have published our first paper on the noise properties of our ultra small tunnel junctions, where we discovered that small area magnetic tunnel junctions at 10K actually had several orders of magnitude lower noise than the standard large area devices. Our devices had an area of ~$10^{-10}$ $cm^2$, more than 10 times smaller than previous devices, but the noise is not well described by a 1/f behavior, in contrast to what has been observed for larger area junctions. Furthermore, time domain measurements directly confirm the existence of resistance fluctuations, which are strongly dependent on the magnetic state of the junction and on the applied magnetic field. This dependence strongly suggests that the observed fluctuations and noise mainly occur due to pinning of domain walls during the magnetization reversal process, rather than from charge traps within the tunnel barrier. Determining the origin of this excess noise is relevant for the design of submicron devices working at low frequency for magnetic field sensing applications. Ph.D. candidate **Bochen Zhong** gave a talk on this work at the MMM international Conference in November 2010.

More than 45 faculty and students are using **Webb's** facilities located in both the NanoCenter and EM center for their research. Our Nanoelectronics Center is clearly a success when judged by the amount of external funding received, the number of publications in peer review journals, and the number of national and international invited talks our personnel have given since its inception in 2004.




USC undergraduate Weizhi Xiong at his poster presentation at the Fall2010 DNP meeting in Santa Fe, N.M.

USC undergraduate Kevin Wood in the test lab at Jefferson Lab, Newport News, Va., working on the kaon aerogel detector

# Experimental Nuclear Physics Group

The intermediate-energy Experimental Nuclear Physics (ENP) Group is a large research group in the Department of Physics and Astronomy. We are five faculty members: Chaden Djalali, Ralf Gothe, Yordanka Ilieva, Steffen Strauch and David Tedeschi. Other members of our group include three postdoctoral researchers, seven graduate students and several undergraduate students. This past year was very successful for us, and we are happy to share the latest ENP news.

The study of the atom's nucleus and its constituents on the quark level is the core of our research. We are leading 11 experiments at one of the flagship facilities for nuclear physics research in the United States, the Thomas Jefferson National Accelerator Facility (Jefferson Lab, or JLab). We are also engaged in collaborative research at the J-PARC proton accelerator in Japan and the electron accelerator MAMI in Mainz, Germany. Our studies focus on quantum chromodynamics and nuclei and are recognized as U.S. nuclear science frontiers. The main questions our research addresses are: What is the internal landscape of the nucleon? How do the properties of strongly interacting particles change in the nuclear medium? What governs the transition of interacting quarks and gluons to pions and nucleons? and What is the nature of the nuclear force that binds quarks into protons and neutrons and nucleons into nuclei? In the past year alone, the members of our group presented our research and findings on these topics at 30 invited talks and seminars at the national and international levels, which is a token of the international recognition of our group, as is the fact that we published dozens of articles on our collaborative research.

Some highlights of our recent research accomplishments include the approval of two new USC-led experiments for the upgraded 12-GeV Jefferson Lab, *Nucleon Resonance Studies with CLAS12* (R. Gothe et al.) and *Proton Recoil Polarization in the* $^{4}He(e,e'p)^{3}H$, $^{2}H(e,e'p)n$, *and* $^{1}H(e,e'p)$ *Reactions* (S. Strauch et al.). Given the high level of competition for beam time, we are very proud of such recognition of the quality and importance of our program at this facility. Two of us were invited to present a series of lectures at the Hampton University Summer School (HUGS), which each year hosts nuclear-physics graduate students from around the world for three weeks in Newport News, Va. In 2010, Gothe discussed *Nucleon Resonance Structure at Large* $Q^2$, and this year, Strauch delivered lectures titled *Hadrons in the Nuclear Medium*.

2011 ENP annual retreat held at the Department of Physics and Astronomy on Columbia Campus. Sitting (from left to right): Hao Jiang, Yuqing Mao, Arjun Trivedi, Yordanka Ilieva, Evan Phelps, Lewis Graham, Gleb Fedotov and Jesse Anderson. Standing (from left to right): Dong Xue, Mike Paolone, Weizhi Xiong, Gary Hollis, Ye Tian, Kevin Wood, Chaden Djalali, Ralf Gothe, Rob Hedrick and Felician Stratmann. Missing: Steffen Strauch (photographer), David Tedeschi, Slava Tkachenko and Wondessen Gebreamlak.



Thanks to our continued funding from the National Science Foundation and funding support that we succeeded to negotiate with the Jefferson Laboratory, we continue not only to support postdoctoral fellows and graduate students but also to provide unique research opportunities for USC undergraduates. In fall 2010, our student Weizhi Xiong presented the results of his research under the supervision of Y. Ilieva, *Extraction and Test of Beam Spin Asymmetry in the reaction* $\gamma d \rightarrow pp\pi^-$, at the annual meeting of the Division of Nuclear Physics (DNP) in Santa Fe, N.M. His poster presentation was enthusiastically accepted and strongly acclaimed by participating nuclear scientists. Currently, Weizhi is working on a new research project with our group that investigates the interaction of particles containing a strange quark and will constitute his senior thesis. In 2011, our student Kevin Wood spent a full summer at Jefferson Lab working on a new kaon detector for the Hall-C upgrade to 12 GeV. We are looking forward to another strong representation of our undergraduate students at the fall 2011 DNP meeting.

With respect to the JLab at 12 GeV, our group has a major part in the upgrade project with the development and construction of a new addition to the Time-of-Flight (TOF12) spectrometer for the CLAS detector in Hall B (R. Gothe) and the development of a kaon detection system for Hall C (Y. Ilieva). Testing and prototyping of TOF12 detector elements has been performed in the Neutron Generator Building at USC. Our significant efforts in designing and prototyping the detector elements have been rewarded with achieving a world-record timing resolution! Our work scored high marks recently in an external technical review by JLab scientists. We expect to begin production in fall 2011 and will complete the installation at Jefferson Lab in fall 2013.

In summer 2011 we held our first annual group retreat in which all members of our group joined together for a full day of physics presentations and discussions of latest results and future plans. The meeting was a great success not only from a scientific point of view but also due to the opportunity it gave to new and to off-campus group members to get to know and to be introduced to the rest of us. We hope that this first event will initiate a long and successful tradition of joint annual meetings.

## Nuclear Theory Group

**Faculty: Professors Fred Myhrer and Kuniharu Kubodera**

The academic year 2010-2011 saw some changes in our group. Last fall Professor Kubodera, in consideration of his retirement schedule, decided not to participate in our new National Science Foundation proposal, but he continues to participate actively in our research group. In the spring we were notified that our three-year research proposal was accepted by NSF with funds to hire a postdoctoral fellow for the duration of the grant.

Dr. Udit Raha joined our group as a postdoctoral fellow in August 2010. Unfortunately for our group, however, he has been offered a faculty position at the Indian Institute of Technology at Guwahati and has to leave our group during the current academic year. We are of course very happy for Udit, though.

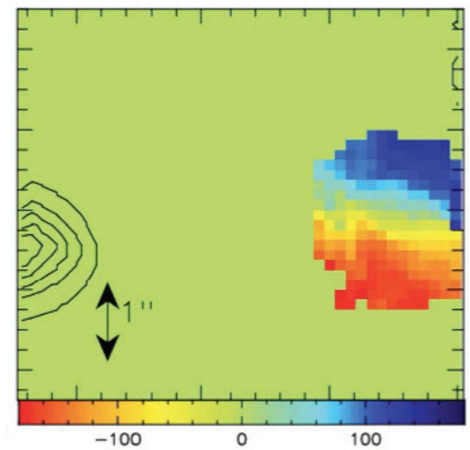
One of our main research topics at this moment is concerned with the highly consequential neutrino-oscillation experiments currently under way at the Daya Bay reactor in China and at the Chooz reactor in France, both involving large international collaboration groups. These experiments utilize anti-neutrinos from nuclear reactors to determine an important but elusive quantity (known as $\Theta_{13}$ among specialists) that describes a mixing of different neutrino species. The envisaged accuracy of these experiments requires a detailed study of what is known as radiative corrections. The USC group is in a unique position to be able to evaluate these radiative corrections very accurately with the use of an effective field theory approach, and we are busy doing this evaluation.

As another application of this powerful approach, we are carrying out a high-precision calculation of radiative corrections for muon capture on the deuteron. The rate of this reaction is currently measured with unprecedented accuracy at the Paul-Scherrer Institute in Switzerland. It is noteworthy that this experiment will allow the accurate determination of a certain parameter (a low-energy constant in our jargon) that affects the rates of several other nuclear reactions that are of great importance in astrophysics and particle physics. Two examples are the neutrino-deuteron reactions and the proton-proton fusion reaction occurring in the sun. The expected precision of the PSI experiment is such that here again the relevant radiative corrections need to be evaluated very accurately. An effective-field-theory calculation of these radiative corrections we are currently carrying out will allow the accurate extraction of the value of the above-mentioned parameter from the PSI data.



Reflecting the established international recognition of our group, we were solicited to contribute review articles for two renowned invitational review journals, the Review of Modern Physics and the Annual Review of Nuclear and Particle Science. These articles were published during the academic year 2010-2011. Furthermore, Kubodera was invited to contribute a review article to a Festschrift in honor of the 85th birthday of Professor G.E. Brown, one of the leading figures in the world nuclear physics community. For this Festschrift, Kubodera together with M. Rho (Saclay, France) wrote an extensive review on nuclear chiral perturbation theory.

In December 2010, our graduate student, Rebecca Bowers, defended her master thesis, "Neutrino Oscillations: 80 years in Review." She is now pursuing her Ph.D. study in astrophysics at Lehigh University, Pa. Jim Talbert, an undergraduate student, also joined our research team last year. He and Reggie Bain were both awarded a Barry M. Goldwater Scholarship in 2011. See a separate column on p. 3 regarding this prestigious national award. Jim continues to work in our group during his senior year.




3-D "Doppler" map of hydrogen emission from a distant galaxy (near the right) detected by means of absorption in the spectrum of a background quasar (position denoted by contours on the left). Colors denote the velocity of the glowing interstellar gas in km/s, relative to the mean velocity of the galaxy. Clear separation between the blue and red suggests a rotating galaxy. This image, from our Very Large Telescope data (Peroux et al. 2011), is one of the first 3-D maps obtained for a quasar absorber galaxy. The light we receive from this galaxy left that galaxy 7.6 billion years ago! The small scale bar denotes 1 arcsecond.

## Astronomy/Astrophysics

Professor Varsha Kulkarni continued research in extragalactic astrophysics along with her collaborators. Our group uses primarily optical, infrared and ultraviolet facilities in space and on the ground. Our goals are to measure chemical compositions, sizes and star formation rates in galaxies producing absorption lines in quasar spectra and their implications for galaxy evolution over the past ~10 billion years. This work has led to the discovery of a new population of highly enriched galaxies, which may have played a significant role in the cosmic chemical enrichment history (see figure above). We are also studying the composition of interstellar dust grains (necessary "seeds" for the formation of planets) in galaxies near and far. These studies have led to the first detections of silicate dust in quasar absorber galaxies. Additionally, we have recently started to study the structure of a rare class of galaxies known as polar ring galaxies that can help to map the distribution of dark matter in galaxies (see figure bottom right). Our work is funded by NASA and the National Science Foundation. During the past academic year, we have received three new grants from NASA. Our research resulted in 10 publications within the past academic year, with more papers in preparation.

During the past year, our team obtained new data with several state-of-the-art telescopes: the Magellan Clay telescope and the European Southern Observatory's Very Large Telescope in Chile, the Large Binocular Telescope in Arizona, the Keck Telescope in Hawaii, and the Apache Point Observatory in New Mexico. We have also been awarded time on NASA's Hubble and Spitzer

Space Telescopes, as well as on the Herschel Space Telescope operated by the European Space Agency and NASA.

A recent addition to our group is research associate Dr. Monique Aller, who joined in fall 2010. Aller received her Ph.D. at the University of Michigan and worked at the Eidgenössische Technische Hochschule (ETH) in Zurich, Switzerland, prior to joining USC. Aller is an expert in studies of galaxy evolution and super-massive black holes. At USC, she is collaborating with Professor Varsha Kulkarni on a number of research projects related to the stellar and interstellar matter in galaxies.

Graduate student Lorrie Straka finished a study of the imaging of high-redshift metal-rich quasar absorber galaxies, published recently in the Astronomical Journal. She is currently working on studies of a large number of quasar-galaxy pairs. Graduate student Debopam Som is working on element abundances in high-redshift absorbers. He traveled to Chile for an observing run with the Magellan telescope and will soon be observing with the Japanese Subaru Telescope in Hawaii. Kulkarni and her team gave several presentations at national and international institutions and conferences.

In other news, our group helped organize a play titled "Halley's Comet: Fire in the Sky" written by Dr. Jerred Metz, performed by the USC theatre department at the S.C. State Museum. Dr. Dan Overcash and Mr. Alex Mowery continued their excellent outreach efforts at the Melton Memorial Observatory, where public nights are held on all clear Monday nights. As director of the Astronomy Center, Dr. Soheila Gharanfoli continued her excellent undergraduate teaching work. Kulkarni was elected vice president of the South Atlantic Section of the American Association of Physics Teachers.

Hubble Space Telescope image of NGC4650A, an example polar ring galaxy being studied by us with NASA's Spitzer Space Telescope. Polar ring galaxies consist of a robustly star-forming ring of gas, dust and stars orbiting in a plane perpendicular to the major axis of a central host galaxy. These galaxies offer unique probes of the dark matter in the halo via measurements of rotation rate of the highly extended ring.

## Alumni News

# Jun Suzuki — Ph.D. USC, 2005

Jun Suzuki entered the USC physics graduate program in September 2001 after obtaining a B.Sc. degree from the University of Tokyo, a top elite university in Japan. He chose USC to study in the world-famous Foundations of Quantum Theory Group run by Professors Yakir Aharonov, Jeeva Anandan and Pawel Mazur. Jun worked with these illustrious faculty members on problems in quantum field theory as well as foundations of quantum theory. Under the academic supervision of Professor Pawel Mazur, Jun sailed through the Ph.D. program in less than four years and obtained his Ph.D. degree in May 2005.

Suzuki then went to the National University of Singapore as Professor B.G. Englert's postdoctoral research fellow, and he spent three years there working mainly on the security problem in quantum cryptography. In 2008, Jun moved to the National Institute of Informatics (Japan) as a research fellow of the Quantum Information Science Theory Group led by Professor Kae Nemoto. Among Jun's main research interests was the application of atom-photon scattering theory to quantum information processing protocols. In April 2011, Jun became an assistant professor at the University of Electro-Communications (Japan), a national university specializing in electrical engineering and information sciences. As a member of the Department of Information Network Systems, he is teaching and doing research on information theory, both in the classical and quantum regimes.

One of Jun's motivations to work on theoretical physics is to understand quantum phenomena from the first principle and to explore how the classical world emerges from quantum systems. Jun says he started to be interested in the latter problem under the strong influence of Mazur, his Ph.D advisor at USC. Jun continues to investigate the origin of classical physics and the interface between the macroscopic and microscopic world.

Jun and his wife, Clarice, whom he met during his three-year stay in Singapore, have a baby son born last year, and the young family lives in Koganei, a peaceful residential town on the western outskirts of Tokyo.

# Quantum Leap

Department of Physics and Astronomy
University of South Carolina
712 Main Street
Columbia, SC 29208

Telephone: 803-777-8105
Fax: 803-777-3065
Email: wonge@sc.edu
www.physics.sc.edu

**Chair:**
Chaden Djalali

**Director of Graduate Studies:**
Vladimir Gudkov

**Director of Undergraduate Studies:**
Jeffrey R. Wilson

**Editors:**
Kuniharu Kubodera
Evelyn Wong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