

Quantum Leap

University of South Carolina
Department of Physics and Astronomy

The Loss of Professor Colgate W. Darden III

By Frank T. Avignone III

Colgate W. Darden III, Distinguished Professor Emeritus (alias “Coke”), lost his long battle with cancer on March 12, 2009. Dr. Darden joined the physics faculty in the summer of 1964 as a part-time lecturer in astronomy. Coke received a BS degree in electrical engineering and a Master of Arts at the University of Virginia (UVA) and his



Left to right: Ron Edge, Colgate Darden, Bill Langford, and two students



Colgate Darden

Ph.D. degree in nuclear physics from the Massachusetts Institute of Technology. He had taken courses in astronomy at UVA and maintained an interest as an amateur astronomer. In his first year at the University of South Carolina, he established a modern lecture course in astronomy that was the genesis of the present astronomy program later created by Professor John Safko. Over the years the program developed into the current one that accounts for a significant fraction of the student contact hours of the department.

Although he was paid on the basis of one-third time, he worked full time and was as productive as a full-time tenured associate professor. As time went on, he moved into teaching a number of different physics courses, and in particular was very effective in teaching Physics for Engineers. In these early years, his engineering background was extremely valuable in setting the course standards exactly where they should have been.

In 1965 Darden played a very important role as a mentor to me when I joined the USC faculty on Jan. 1 of that year. Together we wrote a successful proposal to the U.S. Atomic Energy Commission (AEC) to develop a reactor neutrino research program at the Savannah River P-Reactor, the site of the discovery of the neutrino about seven years earlier. Coke Darden’s mature guidance resulted in a successful program and was in no small part responsible for USC’s present internationally known program in low energy neutrino physics and double-beta decay. Several years later Coke was the principal investigator of the AEC grant to develop a modern nuclear physics laboratory. This has been a very successful pedagogical tool that teaches real-world research techniques in nuclear physics, as well as health, medical, and environmental physics.

In the late 1960s, Drs. Darden and Edge led a new effort to establish a program in intermediate energy nuclear physics utilizing pi-meson scattering on nuclei to study the basic nuclear forces. This was carried out first at the Space-Radiation Effects Laboratory (SREL) in Newport, Va. Coke used his private airplane to fly the equipment and personnel to the site, resulting in a very high level of efficiency and the ability for teaching faculty to fully participate. A further development of this program led the group to the Los Alamos National Laboratory Meson Facility (LAMEF). In 1970 the program attracted Assistant Professor Barry Preedom to the University, and the result is the present very successful program that has been well funded for many years now by the National Science Foundation. It was the first cornerstone in steady funding for any program in the department. It remains successful today and has achieved national and international recognition.

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A Message from the Chair



Chaden Djalali

Maintaining Our Momentum— Even During Tough Times

Welcome to another issue of the University of South Carolina Department of Physics and Astronomy newsletter. On July 1, I started my second term as chair of the department, and I continue to be amazed at the levels of activity and excitement characterizing our department, regardless of good or bad budget times. As you are fully aware, the serious financial problems, which started last year, have affected countless universities, businesses, families, and individuals across the nation and around the world. I am sure you are wondering how our department has been affected. I am pleased to report that so far we have been able to weather this storm by a hiring freeze that has left two faculty and two staff positions temporarily unfilled and by modestly reducing the number of graduate teaching assistant positions. During these tough times, the commitment of the faculty, the dedication of the staff, the enthusiasm of our students, and the support of the administration and our engaged alumni and friends have been instrumental in helping the department not only maintain its momentum but substantially increase the quality and quantity of its

enrolled students, the amount of extramural funding and its scientific productivity. Most of these achievements are described in this newsletter.

I am delighted to report that Professor Steffen Strauch was granted tenure and that Professor Vladimir Gudkov was promoted to the rank of full professor with tenure. Congratulations to Professor Yaroslav Bazaliy for getting the prestigious National Science Foundation (NSF) Career Grant. I also note sadly the passing of Distinguished Professor Emeritus Colgate W. Darden III, who played a major role in creating three important research areas in our department. He will be missed as a friend, an outstanding scholar, and a generous benefactor of our department.

As far as the immediate future is concerned, there is no guarantee that we have touched the “bottom” of the financial crisis. Additional budget cuts have been announced, but nobody is letting their foot off the pedal as there is much work still to be done, and we are all committed to preserving our key teaching and research missions. You can be assured that the support of our alumni and friends is appreciated (and needed) more than ever. Thank you for your generous support of our department. We hope that you will stay in touch with all of us.

Darden continued from pg. 1

The next major milestone in the long list of outstanding contributions of Colgate Darden came in 1977 when he took a leave of absence in Hamburg, Germany, at the Deutsches Electron Synchrotron (DESY) Laboratory. This was very shortly after the psi particle had been discovered, and there was a race on to attempt to observe the upsi-lon particle and its excited states. Darden proposed to the laboratory leadership the restoration of the decommissioned Double Arm Spectrometer (DASP) to working order. He and his colleagues instrumented it to search for the upsi-lon and several excited states. This energy was just out of reach of other accelerators at that time. By the time he returned to USC in May 1978, the search was successful; the DASP experiment observed the upsi-lon (Υ) and measured the energies of both the first and second excited states, Υ -prime, and Υ -double prime. These results were world-renowned and

won Darden the Russell Research Award for his leadership in the project. These experiments and their results were described in the famous text on elementary particle physics by Professor Lev Okun, a famous Soviet scientist at the Institute for Theoretical and Experimental Physics (ITEP) in Moscow.

Because of these successes, Coke was invited to take a leadership role in the construction of the central vertex wire chamber of the new ARGUS detector at DESY to carry these investigations further. He involved Professor Richard Childers (now deceased), who had left research, and they built an effective team. They obtained funding to alternate semesters in Germany as run chiefs during the operation of the experiment. During the next few years, the collaboration measured the spectroscopy of the D^* and F^* mesons and the hyperon. This was the solidification of the establishment of a viable program

in high-energy physics in the department. Following the successful activities at DESY, Darden and Childers established a research program at the Fermi National Laboratory in Batavia, Ill.

These successes led to the attraction of Carl Rosenfeld to USC as the heir apparent to lead the program and later to the addition of Jeff Wilson, Milind Purohit, and more recently Sanjib Mishra and Roberto Petti. This is a highly successful program, representing a large part of the cutting-edge research and funding in the department.

Darden retired in 1994 but remained in contact with many members of the department until his death. As a legacy, Colgate Darden made important contributions in the creation of three important research programs in the Department of Physics and Astronomy. He will be missed as a friend, colleague, and benefactor of our department.

Condensed Matter and Nanoscale Physics Group

By Scott Crittenden and Thomas Crawford

Spintronics Theory Group Coming Up to Speed

For the past year the Spintronics Theory Group, led by Yaroslav Bazaliy, has been working on improving our understanding of the efficiency of memory nano-devices. They investigated a particular type of nano-machines that use the phenomenon of spin-transfer to switch the state of a tiny magnetic structure. The central piece of the device is a pair of two discs having the radii of about 50 nm and being just 3 ± 5 nm thick. The disks are magnetic, and they are built so that in the absence of external influences their magnetic moments stay in two equally possible configurations. Carefully fabricated metallic contacts allow one to attach an external battery to the device and pass electric current between the disks. Here comes the central part of the story. Due to a wonderful interplay of quantum physics and electron transport, it happens that the current can switch the magnetic state of the disks between the two stationary configurations described above. As any two-state switchable system, the device can be used as a memory cell containing one bit of information.

The practical application of the spin-transfer memory cells requires making the switching current as low as possible. But what determines the current threshold, and how can one predict it? This question has been discussed for a while in the spintronics community. So far, it was found that many factors can contribute, and their relative importance depends on a particular situation. Designing a spin-transfer device was a little like purchasing a new computer: one gets bombarded by 10 to 15 parameters, each of which is claimed to be “very important” by the manufacturer. Comparing different models quickly becomes a nightmare. Wouldn't it be nice if there were a single figure of merit for a spin-transfer device? Together with a master's student, Inti Sodemann, Bazaliy has shown that for a wide class of structures all parameters enter the formula for the critical current in just one combination, which we named the “spin torque efficiency.” With a single figure of merit, the decision making becomes much simpler, and we expect that our work will help to engineer better spintronic memory cells. The paper reporting our results is currently being considered by *Physical Review Letters*.

Overall, the previous academic year was fruitful for the group. They have one master's thesis successfully defended. Their research professor, Revaz Ramazashvili, published a paper on electric excitation of the magnetic resonance modes in materials with a special form of spin-orbit interaction. His work on spin-orbit interaction in antiferromagnets resulted in a wide interest in the community and an offer of a permanent position at CNRS, France. A fruitful interaction is going on with the experimental groups of Professor Richard A. Webb and Thomas M. Crawford at USC. Recently we started a promising collaboration between the experimentalists and theorists here at USC and the group of Professor S. Urazhdin at West Virginia University, who will provide samples for the ultrafast pulse studies performed at the USC Nanocenter. Finally, Bazaliy, as a group principal investigator, received a National Science Foundation (NSF) Career grant, which provides \$420,000 of funding for the next five years to continue his research in the field of spintronics and nanomagnetism. With all those developments, the group is off to a great start.

Faculty members

Yaroslav Bazaliy, Thomas Crawford, Rick Creswick, Scott Crittenden, Timir Datta, James Knight, Milind Kunchur, Yuriy Pershin, and Richard Webb;
NDSEG graduate fellow: Tyler Ray

Research assistant professor

Samir Garzon

Visiting Professor

Sukru Cakmaktepe, Kilis 7 University, Turkey

Postdocs

Yuan Zhen Chen, Shifan Shi, Ro Chen Zhong, and Longfei Ye

Graduate students

Longfei Ye, Yuqing Mao, Wondesen Gebreamlak, Tareif Khatib, Tyler Ray (mechanical engineering), Jing Yang, and Zhelin Sun

Undergraduate students

Rob Hedrick, Jason Henderson, Olivia Keyes, and Chris Pasco

The renaissance in condensed matter and nanoscale physics continues. With strong successes obtaining funding, new laboratories nearing completion, and exciting projects ongoing or recently launched, the condensed matter and nanoelectronics faculty offer a feast of on-campus, table-top experimental and theoretical research opportunities for students and research associates. They expect this excitement to continue to build as the new research programs ramp their output to full steam.

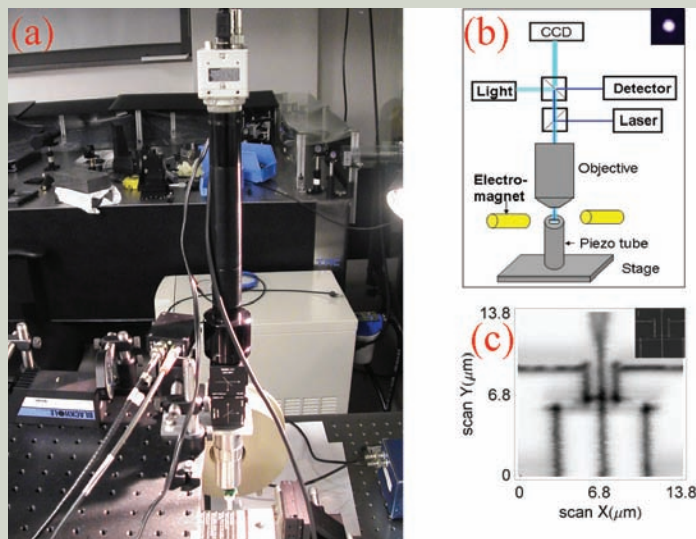
Condensed Matter and Nanoscale Physics Group

Spinning at the Picoscale

Professor Thomas Crawford's laboratory for picoscale metrology and nanomagnetism saw 2008 end with the graduation of two master's degree students, Brad Knaus, and Abraham Pernicka, and 2009 began with the group having to completely vacate its laboratory in Sumwalt for an attempt to seal the floor against moisture and install a new conductive flooring system. It also began with two new postdoctoral associates, Dr. Shifan Shi from the University of Alabama and Dr. Michael Katkov from Michigan State University, and a new Ph.D. candidate, Yuqing Mao. Shi, Katkov, and Mao joined Ph.D. candidate Longfei Ye, research professor Dr. Samir Garzon, and undergraduate physics major Jason Henderson, already hard at work on nanomagnetism and spintronics.

Dr. Shi has taken the lead on a three-year NSF-funded project, "Reprogrammable Parallel Nanomanufacturing." Working with Henderson, Shi employs the tiny magnetic fields emanating from the surface of a magnetic recording disk to trap iron-oxide nanoparticles. These fields are written into arbitrary nanoscale patterns using a magnetic recording head, and after assembling the nanoparticles, the disk is coated with an optically curable polymer. Once cured, the polymer is peeled from the surface, transferring the nanoparticle pattern to a flexible and optically transparent substrate. This project has further expanded as part of a new collaboration with Professor Sarah Baxter from mechanical engineering. Here NDSEG graduate fellow Tyler Ray has been working in Crawford's lab to align gold nanorods using oscillating electric fields for inclusion in nanocomposite materials. Crawford believes this interaction and a nascent collaboration with several materials scientists at Clemson has potential to eventually lead to the creation of a South Carolina Center for Nanomanufacturing.

Dr. Katkov, supported by ARO and medical physics consultants, has been using electronic transport in ultrathin gold films to detect the presence of DNA on the Au surface. In particular, he has identified instability in a composite layer designed to prevent extra DNA from sticking to the surface. The group expects this result will have a big impact on developing approaches for assembling and detecting DNA and other macromolecules on surfaces. Meanwhile, Mao has begun to implement a surface second-harmonic generation (SHG) apparatus for detecting magnetic properties of organic layers assembled on metallic surfaces, looking in particular for unique magnetic properties reported to occur at the interface between these layers and the underlying metallic support film.



Finally, Dr. Garzon and Ye continue to make wonderful progress further establishing a new experimental technique, invented in Crawford's lab at USC, for studying magnetodynamics in single nanomagnets. Results obtained with this technique were published in fall 2008 in a *Physical Review B Rapid Communication* that was selected as an editor's pick and as the subject of an edition of *Viewpoint in Physics: Spotlighting Exceptional Research*. By using some of the world's shortest electrical pulses, in combination with fast-rise time and precisely timed longer current pulses, Ye and Garzon successfully employed spin transfer torque to both excite coherent precession and cancel damping in a nanomagnet, demonstrating a greater than twofold increase in precession time, with little decrease in amplitude or coherence for over two ns. Their results demonstrate the ability to use tailored pulse shaping for coherent control to study the fundamentals of magnetism in these idealized nanoscaled magnets. The results of the damping cancellation study are currently under review at *Applied Physics Letters*. Crawford is looking forward to strong success in 2010, with advances on all three ongoing projects, and extends a warm welcome to any and all visitors who would like to take a tour of our growing facility in the Sumwalt NanoCenter.

Condensed Matter and Nanoscale Physics Group

Bacteria Manufacture Conductive Bionanowires

Professor Scott Crittenden's group has made good progress on the project funded by last year's three-year, \$287,000 ARO grant to understand the conductivity of the bionanowires produced by electrogenic bacteria, utilizing the bacterial fermenter acquired from a second ARO grant of \$37,000. Crittenden has begun collaborations with chemistry professor Qian Wang on bionanowires, with Professor Brett Altschul on nanoscale surface mediated aqueous conduction, and with Dr. Jim Sumner (Army Research Laboratory) on both the aqueous conduction project and developing new measurement techniques with the atomic force microscope.

The group consists of three students working on various projects: Frank Grimmer; Rob Hedrick, an undergraduate; and Jing Yang, who is working toward his master's degree. In addition, Zhelin Sun has decided to test the waters by spending the summer and this semester working on various nanoscale projects.

The group also expects to add an undergraduate student from Professor Wang's lab who will work on bionanowires. In addition, Crittenden hosted six high school students for a week during the Nanoscience Summer School, organized by Professor Wang. They spent three hours a day in the laboratory building microbial fuel cells under the watchful eye of Rob Hedrick and even made it into various newspapers and onto the local TV news. Finally, Crittenden has received \$118,000 from the University to create an advanced 500-level biophysics lab using optical tweezers. He expects to offer the course in fall 2010 in collaboration with Professor Bazaliy.

Supercurrents and Superfast Acoustics

Professor Milind Kunchur's research group continues to work in the areas of superconductivity and psychoacoustics. In the former field, a recent result that attracted worldwide attention is the first real-time demonstration of "Ballistic Acceleration of a Supercurrent." This is one of the most primitive but elusive current-voltage responses of a superconductor in which this quantum system displays a Newtonian-like response. The technique opens doors for the controlled investigation of other time-dependent transport phenomena in condensed-matter systems. This result was published in *Physical Review Letters* in 2009 and will be presented at invited talks at conferences in Japan and Ukraine in the same year. Kunchur continues to be funded by a grant from the U.S. Department of Energy. He is also continuing his collaboration with Jim Knight on a wide variety of issues in superconductivity.

On the psychoacoustics side, Kunchur's group has completed its studies demonstrating microsecond time resolution in human hearing. Besides the impact this result has had on the psychoacoustics and auditory neurophysiology communities, it is having a major impact on audio engineering and high-fidelity equipment fields because of its implications for digital audio and coding standards. The results are being heatedly discussed on many Internet forums (e.g., hifcritic, hydrogenaudio, stereophile, gearslut, naim-audio, theaudioexchange, audioannex, analog-forum.de, etc.), and a British HiFi magazine *HiFiCritic* recently wrote a full feature article on Kunchur's research in this field.

Kunchur's previous graduate student, Gabriel Saracila, graduated in 2008 and is currently employed with General Electric Corporation. His undergraduate student, Mathew Rhoades, also graduated in the same year. This year there are two new graduate students, Manlai Liang and Huaizhou Zhang, and an undergraduate student, Craig Powers, working in Kunchur's group.

Computational Nanoelectronics Studying Circuits and Spins

Assistant Professor Yuriy V. Pershin is the leader of the computational physics group, which has had an exciting year. Graduate student Julian Martinez, who recently joined the group, has been exploring new types of electronic devices with memory: memristors and memcapacitors. These elements typically show pinched hysteretic loops in the two constitutive variables that define them when they are subject to a periodic drive and behave as non-linear elements at low frequencies and as linear devices at high frequencies. However, unlike the memristor, a memcapacitor can store energy. Combined with a recently introduced meminductor, such elements open up new and unexplored functionalities in electronics. In addition, since these are analog devices, they may help us understand adaptive and spontaneous behavior, or even learning, and thus the origin of the workings of the human brain and possibly of many other mechanisms in living organisms.

Another direction of Pershin's group research is semiconductor spintronics. Together with colleagues from Los Alamos National Laboratory, Professor Pershin has proposed and simulated a spintronic device to generate spin polarization in a mesoscopic region by purely electric means. The main idea is to combine the spin Hall Effect with the stirring effect in a closed geometry. Such a device structure does not require the application of magnetic fields, external radiation, or ferromagnetic leads and can be implemented in standard semiconducting materials.

Condensed Matter and Nanoscale Physics Group

Mechanizing Physics at the Nanoscale

Richard Webb's group is working on a variety of collaborative projects on nanoscale spintronic quantum systems, including one-dimensional semiconductor nanostructures, magnetic tunnel junctions, and the development of NanoElectroMechanical Systems (NEMS) for the detection of single spin angular momentum changes and sensor applications.

We have several programs for growing and characterizing 10–50 nm diameter nanowires of SiC, GaN, and InN and making new devices for electronics applications. Although we use e-beam lithography for making small 25–100 nm catalyst spot sizes from which we can initiate nanowire growth, some of our nanowires after growth are so small that we cannot really image and make electrical contact to them.

We have had to send our samples elsewhere for complete characterization, thus experiencing significant delays in our program. Webb has decided to use some of his start-up money to purchase a scanning field emission electron microscope and have it housed in our electron microscopy center so that everyone on campus can have access to it. It will have one nm resolution at 15 keV and the capability to image nonconducting samples using a gas injection system. It will be equipped with energy dispersive X-ray spectroscopy (EDS) for elemental identification and eventually with EBSD for crystallographic, grain size, texture, and phase identification. This system will also have a commercial electron beam lithography program and a beam blinder for writing samples as small as 10–25 nm. We expect to take delivery near the first of the year in 2010.

With Professor Yuriy Pershin and in collaboration with Argonne National Laboratories, we have started a program to measure the spin Hall Effect in both normal and semiconducting materials. In the spin Hall Effect, electrically induced spin polarization accumulates near the edges of a channel and is zero in its central region. This effect is caused by deflection of carriers moving along an applied electric field by extrinsic and/or intrinsic mechanisms. In a nonmagnetic homogeneous system, a charge voltage does not accompany spin accumulation because two spin Hall currents (due to spin-up and spin-down electrons) cancel each other. Preliminary theoretical work has demonstrated that in a system with an inhomogeneous electron density profile in the direction perpendicular to the direction of main current flow, the spin Hall Effect results in both spin and charge accumulations at the edge of the sample, resulting in a transverse voltage that is different from the normal Hall Effect. It has an unusual quadratic dependence on the longitudinal applied electric field. In addition, we will search for the two new predicted effects: frequency doubling (or second harmonic generation) and a spins memory effect.

Rick Creswick continues to devote most of his time in collaboration with Frank Avignone to searches for neutrinoless double beta decay and particles of dark matter (WIMPs). While these experiments touch on the frontiers of particle astrophysics, the techniques used are pure condensed matter physics. In addition, he continues his research in fundamental problems in statistical physics, including time reversal and the second law and critical phenomena.

Gravitation and the Macroscopically Quantum

Professor Timir Datta and his students have been working on a number of topics, principally in the areas of gravitation, quantum optics, and macroscopic quantum effects.

In a recent article titled "Do Quantum Systems Break the Equivalence Principle?" they pointed out that in a gravitational field, g , the bulk response of an electrically neutral but atomistic test mass is model dependant. Opposing results for the gravity-induced (electric) polarization P have been reported in the literature. For instance, P is small and oriented antiparallel to g if the deformations of the positive background lattice is neglected, but it is about $\sim 100,000$ times larger and opposite in direction in the elastic lattice approximation. Surprisingly, the rigid system is consistent with EP, but the elastic system breaks EP. This article was featured as the "Best New Idea" by the Physics arXiv blog (www.technologyreview.com/blog/arxiv/24050) in the Aug. 28, 2009, issue of the *Technology Review* published by MIT. In optics, they have designed a new interferometer that shows entanglement between negative positive and negatively reflected photons. Quantum Hall Effect in antidot lattice is another subject of interest; this group was the first to observe QH condensation in carbon, long before graphenes were discovered. Just this year, in April, a paper from Louie's group at Berkeley theoretically predicted that patterned two-systems with holes should show quantum condensations. Datta's system is replica opals of CVD carbon, a 3-d antidot lattice.

This group is continuing its research collaboration on superconducting and magnetic materials at the Naval Research Laboratory in Washington, D.C., and is funded by the ONR. It includes a study of the iron-based superconductors. The iron system or the pinctides are especially puzzling because even at room temperature, they are strongly ferromagnetic. The magnetic moments break directional symmetry and hence time reversal is a prerequisite in the conventional understanding of superconductivity.

Particle Astrophysics Group

By Frank T. Avignone III

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 University of South Carolina group was early in the field when it made the first 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 University's 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 South Carolina group played a leading role in 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 of quantum chromodynamics do not violate charge-parity (C-P) symmetry. The experiment was based on an analysis developed at the University of South Carolina by an international collaboration led by Richard Creswick. It used 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. Other groups have used this technique worldwide.

The University's 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). $0\nu\beta\beta$ -decay also violates the law of lepton-number conservation. Neutrino oscillation experiments imply that neutrinos may well have enough mass to allow this decay to be measurable, but they can only measure mass differences. The measurement of the decay rate would determine the absolute masses of all three neutrino mass eigenstates.

The USC group was 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 ^{133}Te of $2.5 \times 10^{24} \text{ y}$. CUORICINO is 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 2010 in the CUORICINO cryostat. 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 to build and operate a one-ton experiment in the U.S. Deep Underground Science Laboratory (DUSL). This experiment is further in the future. All these activities are supported by major grants from the National Science Foundation.

Faculty members

Frank Avignone, Richard Creswick, Horacio Farach, and Carl Rosenfeld

Postdoctoral research associate

Iulian Bandac

Graduate students

Carlos Martinez, Leila Mizouni, and Seth Newman

Recent Ph.D. graduates

George S. King (2007) and Todd Hossbach (2009)

Nuclear Theory Group

By Kuniharu Kubodera

Faculty members

Professors Fred Myhrer and Kuniharu Kubodera

Continuously funded by the National Science Foundation since 1982, the Nuclear Theory Group has been investigating the relation between nuclear phenomena and the underlying fundamental dynamics of quarks and gluons. The study of the neutrinos (fundamental particles emitted in, for example, nuclear beta-decay) and nuclear astrophysics are also among our major research topics.

Over the years our group has served as a hub for active international collaborations, and during the last 12 months we carried out joint research projects on neutrino physics and astrophysics with two prominent visitors: Professor Tae-Sun Park (Sungkyunkwan University, Korea) and Professor Toru Sato (Osaka University, Japan).

Reflecting the established international recognition of the University of South Carolina group, we have been solicited to contribute review articles for three invitational review journals: the *Journal of Physics*, the *Review of Modern Physics*, and the *Annual Review of Nuclear and Particle Science*. Kubodera has also been invited to give a talk at the Erice Conference in Italy, one of the most prestigious international meetings in our field. In October 2008 Myhrer gave an invited talk on the spin content of the proton at the 18th International Spin Physics Symposium (SPIN2008) in Charlottesville, Va.

Kubodera continues to serve as a member of the editorial board for two professional periodicals: the *Journal of Physics G* (nuclear and particle physics) and *The Open Nuclear and Particle Physics Journal*.

Our group's most recent Ph.D. graduates, Drs. Ivan Danchev and Barbara Szczerbinska, continue to pursue successful careers as young faculty members, Ivan at Mount Olive College (N.C.) and Barbara at Dakota State University (N.D.). Barbara's recent article on neutrino-nucleus reactions can be found at the arXiv site: <http://arxiv.org.abs/0908.3837>.

Experimental Nuclear Physics Group

By Yordanka Ilieva

Our experimental intermediate-energy nuclear physics group conducts fundamental research of the atom's nucleus and its constituents on the quark level. Our experiments with multi-GeV photon and electron beams are done at one of the flagship facilities for nuclear-physics research in the United States, the Thomas Jefferson National Accelerator Facility (Jefferson Lab). In the last long-range plan, the Nuclear Science Advisory Committee (NSAC) identifies three research frontiers in the U.S. nuclear science: quantum chromodynamics, nuclei and nuclear astrophysics, and fundamental symmetries and neutrinos. Our group is actively exploring key aspects of each of these frontiers. More specifically, our research addresses questions such as 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 quarks and gluons into pions and nucleons, and what is the nature of the nuclear force that binds protons and neutrons into nuclei?

We continue to maintain strong research and initiate new activities on these topics. We are spokespersons of nine approved experiments at Jefferson Lab, with the latest experiment being accepted earlier in 2009. The members of our group have given 24 invited talks and seminars in the past year alone, which is a token of the international recognition our group is receiving. We have published dozens of articles on our collaborative research. In summer 2009 our group secured funding for the next three years from the National Science Foundation at a significantly increased level. Our participation in the Jefferson Lab's 12 GeV upgrade is getting more intense as construction began in spring 2009. Our group has a major part in the upgrade project with the development and design of a new addition to the time-of-flight spectrometer for the CLAS detector in Hall B. Testing and prototyping of detector elements are performed in the Neutron Generator Building at USC. Our hard work in the past year was rewarded with the achievement of a time resolution that surpasses the requested design values.

Congratulations to four of our graduate students—Nathan Baltzell (Ph.D.), Mike Paolone (Ph.D.), Shakil Mohammed (MS), and Lewis Graham (MS)—who successfully graduated in the past year. Lewis continues to work with us in pursuing his Ph.D. degree, while the other graduates are well into their research careers.

Faculty members

Chaden Djalali, Ralf Gothe, Yordanka Ilieva, Steffen Strauch, and David Tedeschi; two postdoctoral research associates, 10 graduate students, and several undergraduate students



Two of our graduate students obtained their Ph.D. degrees in the past year: Nathan Baltzell (left) and Mike Paolone.

Department News

Astronomy Group

By Varsha Kulkarni

The year 2009 marks the 400th anniversary of the first uses of an astronomical telescope by Galileo Galilei and is being celebrated worldwide as the International Year of Astronomy. The University of South Carolina astronomy group has had its share of the fun, working on research, education, and outreach.

Professor Varsha Kulkarni continued research in extragalactic astrophysics along with graduate students and other collaborators. Our work is funded by NSF and NASA, and has just received a new three-year NSF grant. Our group uses primarily optical, infrared, and ultraviolet facilities in space and on the ground. New data were obtained with the Magellan Clay telescope and the European Southern Observatory's Very Large Telescope (VLT) in Chile, the Multiple Mirror Telescope in Arizona, and the Apache Point Observatory (APO) in New Mexico. 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 help in part to solve the "missing metals puzzle." We are also working on a Spitzer Space Telescope program for infrared spectroscopy of quasars to study the cosmic evolution of interstellar dust. Our research resulted in seven publications within the past academic year. Several more papers are in preparation.

Graduate student Soheila Gharanfali completed her Ph.D. dissertation, "High-Resolution Imaging and Spectroscopic Confirmation of Quasar Absorber Galaxies," in summer 2009. She has now joined our faculty as an instructor of astronomy. Graduate student Legna Torres completed her MS dissertation, which showed the detection of interstellar silicate dust in four distant galaxies using the Spitzer Space Telescope. Graduate student Lorrie Straka has just finished a study of emission-line imaging of a few galaxies in quasar fields submitted recently to the *Astronomical Journal*; she is currently working on integral field spectroscopy of other absorber galax-

ies obtained with the Gemini telescope in Hawaii. Graduate student Debopam Som is working on spectroscopy of gravitationally lensed quasars and element abundances in high-redshift absorbers. He traveled to Chile in September 2009 for an observing run with the Magellan telescope. Som, Straka, and Torres presented their work at the seventh annual meeting of Astronomers in South Carolina in April 2009. Som and Straka also gave talks about their work at the second student conference organized by the department in August 2009. Professor Kulkarni gave talks at the 27th meeting of the Astronomical Society of India; at an international workshop on "Detecting Galaxies in Absorption" in Chicago, Ill; at the seventh meeting



One of the perks of studying astronomy is the opportunity to visit some of the world's most scenic mountaintops for observations of the night sky. The left picture shows graduate student Lorrie Straka standing next to the 6.5 meter diameter Multiple Mirror Telescope located at the top of Mt. Hopkins in southeastern Arizona. The right picture shows graduate student Debopam Som at the 6.5-meter diameter Magellan Clay and Baade telescopes located in the southern reaches of Chile's Atacama Desert.

of Astronomers in South Carolina; and at some colloquia/seminars.

In other news, observatory instructor Dr. Dan Overcash was featured on local TV networks WLTX and WACH on the 40th anniversary of the Apollo 11 moon landing. Overcash, who was the director of Melton Memorial Observatory for many years and is now its associate director, continues to inspire University of South Carolina students by teaching astronomy. Alex Mowery has recently taken over as the director of the Melton Memorial Observatory. Mowery, a mathematician by training with

a master's degree in mathematics education, has extensive experience in astronomical observing. He has been an amateur astronomer for a long time and was assisting Overcash at Melton for several years. One of the exciting recent astronomical images captured by our telescopes at Melton is that of the new impact site on Jupiter, created by a comet or asteroid that struck Jupiter on July 19, 2009.

Faculty members

Varsha Kulkarni

Instructors

Soheila Gharanfali, Dan Overcash

Graduate students

Debopam Som, Lorrie Straka, and Legna Torres

Melton Memorial Observatory director

Alex Mowery

Recent Ph.D. graduates

Joe Meiring (2008) and Soheila Gharanfali (2009)



High Energy Group

By Milind V. Purohit and Sanjib R. Mishra

“They Also Serve Who Only Stand and Wait.”

Faculty members

Professors Frank T. Avignone III, Sanjib R. Mishra, Roberto Petti, Milind V. Purohit, Carl Rosenfeld, and Jeff Wilson

Graduate students

Hongyue Duyang, Jae Kim, Chris Kullenberg, Arjun Trivedi and Ryan White

Undergraduate students

Reggie Bain, Matt Seaton and Andrew Scott

Postdoctoral fellows

Drs. Azizur Rahaman and Xinchun Tian

This famous line from Milton comes to mind as we watch a growing number of graduate students waiting for the LHC to start up. Yes, now the LHC experiments weigh in at roughly two kgs. (that’s a new unit: kilo graduate students!). Our own graduate student Arjun Trivedi is now at CERN for this academic year. He is learning the ins and outs of the LHC beam monitoring system and is writing code to put up beam displays in the control room. He hopes to be in the ATLAS control room the day beam turns on! This is an exciting and rare opportunity for a graduate student at CERN these days, given the competition. While at CERN, he is also helping the South Carolina group with our work on muon detectors. In the new academic year another graduate student on ATLAS, Hongyue Duyang, joined us.

So what went wrong with the LHC? In September 2008 there was an “incident” caused by a faulty splice in the high-current superconducting cable between two magnets. Splice resistances need to be measured to great accuracy and precision and are fairly small (nano-ohms). A new system for measuring these at the relatively high temperature of 80 K is currently being validated. If it works, the time needed for rewarming will be greatly reduced in future runs of the LHC. Current plans call for initial running at 3.5 TeV per beam, half the design energy. Among other changes are new relief valves, an improved ultrahigh-vacuum system, and improved floor anchors for the accelerator magnets to the floor. Once all these changes have been demonstrated to work safely, we can contemplate moving to higher energies.

Another fantastic opportunity came the way of undergraduate Reggie Bain. He presented a poster at the ATLAS Physics of the Americas 2009 meeting held at NYU in early August. In this he displayed work we had done on searching for super symmetry (SUSY) and separating it from background in ATLAS data. Currently we have only simulated data, but we have to be ready for beam turn-on in November. How much longer will we have to wait? Tension mounts and tempers fray, but in the end we hope it will all work out. Whether we get to peek over the precipice and see a fantastic world of new particles or find all our expectations completely unfulfilled, we do not know. Stay tuned and read the next issue of Quantum Leap to find out what happened.

Dr. Wochun Park visits CERN often, where he participates in test beam runs for MICRO-MEGAS detectors (as have Professors Roberto Petti and Milind Purohit). Most of Park’s work is on muon detectors: the care and feeding of cathode strip chamber software. This is a large and ongoing effort, and Park’s contributions are critical. (Despite the attention needed by a young family, Park has maintained regular visits to CERN.) We anticipate a peaking of all hardware-related efforts in the coming months due to startup of the beam.

Our other experiment, BaBar, has completed data taking, but analyses continue. Graduate students Xurong Chen and Hongxuan Liu received the Ph.D. degree at the end of 2008. Chen has moved to a position in industry. Liu has continued analysis work with our group pending a move to his next career position. Graduate student Ryan White is doing a splendid job understanding pion track efficiencies and charge asymmetries therein, and he has studied many sub-samples by now (taus, D0s, K-shorts) to make this happen. We hope for a tracking publication in addition to his thesis physics publication. Finally, he hopes to accumulate a large sample of charm data for further processing by other S.C. students at some later date.



Reggie Bain



Arjun Trivedi

High Energy Group

Study of Neutrino Oscillations and of Neutrino Physics

Sanjib R. Mishra, Carl Rosenfeld, and postdoctoral fellows Dr. Azizur Rahaman and Dr. Xinchun Tian continue their pursuit of neutrino oscillation physics in the ongoing MINOS experiment and the NOVA experiment, which is in preparation at Fermilab. NOVA suffered a budgetary setback in federal legislative action in January 2008, but in June the Congress reversed itself, and NOVA is again forging ahead. Mishra, Rosenfeld, and undergraduates also continue work on analysis of the MIPP hadroproduction survey experiment. MIPP will improve understanding of neutrino beam formation and, by controlling systematic error, support the Carolina interest in neutrino oscillation analyses.

Mishra, Petti, graduate students Jae Kim and Chris Kullenberg, and undergraduate students Matt Seaton and Andrew Scott continue their analyses of the voluminous data on neutrino-nucleus interactions compiled by the NOMAD experiment at CERN. The high-resolution capability of the NOMAD detector results in competitive measurements of cross-sections and particle production in neutrino interactions and in precision electroweak measurements. The NOMAD analysis work is an important proof of principle for the new HiResMnu experiment. Several publications of NOMAD analyses are in preparation. One of these, by graduate student Jae Kim, is the most precise analysis to date of quasi-elastic neutrino scattering.

Recent work by Mishra and undergraduates Chris Kullenberg and Matt Seaton has resulted in the most precise measurement of coherent neutral-pion production in neutrino interactions. The analysis has yielded another important result: the most stringent bound on the novel phenomenon called “anomaly-mediated neutrino-photon interaction” (ANP). These results directly impact the neutrino oscillation searches in the NOVA and DUSEL experiments.

Proposal for a New High-Resolution Neutrino Experiment at Fermilab

The Fermi National Accelerator Laboratory (Fermilab) in Batavia, Ill., plans to build Project-X, a new eight GeV proton driver to upgrade the main injector beam line. The project will increase the intensity of the existing NuMI beam by one order of magnitude, making it the most powerful neutrino beam in the world. This enhancement will open new and exciting perspectives for neu-

trino physics—from the investigation of neutrino oscillations and masses to the study of their interactions with matter. Professors Sanjib Mishra, Roberto Petti, and Carl Rosenfeld have proposed a

new high-resolution

experiment, HiResMnu, to exploit the unprecedented neutrino fluxes foreseen with Project-X at Fermilab. A glance at the figure shows the power of the proposed detector. A letter of intent with the description of the detector and of its physics potential was submitted in spring 2009. We presented the ideas at several workshops, and the proposal stimulated great interest in the community. We are currently finalizing the design and expanding the collaboration to other institutions.

As recently discovered by Super Kamiokande, K2K, and MINOS, neutrinos can change their flavor in flight. This results in “oscillations” between different neutrino types, which depend upon a unitary mixing matrix and the mass difference $\Delta m^2 = m_1^2 - m_2^2$. At present we have only upper limits on the mixing angle Θ_{13} and know nothing about the sign of Δm^2 (neutrino mass hierarchy). Furthermore, we do not know to what extent anti-neutrinos behave differently from neutrinos (violation of charge-parity symmetry, CP). The high-intensity beam from Project-X should provide the opportunity to resolve such fundamental issues with long baseline (LBL) experiments (Fermilab to DUSEL, $L=1,300$ km). The experiment we propose, HiResMnu, will reduce systematic uncertainties related to neutrino fluxes and neutrino interactions, thus increasing the sensitivity of LBL experiments to oscillation parameters.

Overall, HiResMnu is expected to collect 140 million neutrino interactions and 50 million anti-neutrino interactions. Such samples are about two orders of magnitude larger than previously collected. This fact, coupled with the high resolution and granularity, will allow, for the first time, tests of electroweak interactions of neutrinos with a precision comparable to what is achieved with e^+e^- colliders (LEP, SLC).

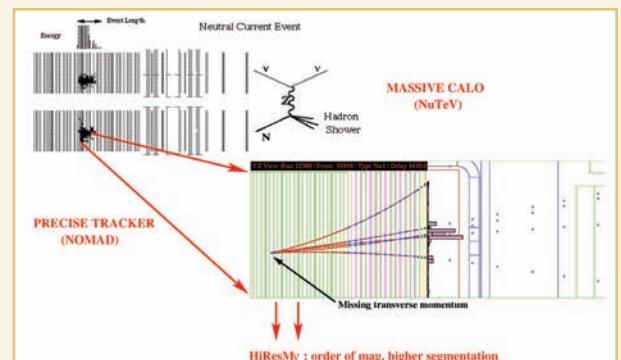


Illustration of the superiority of the NOMAD detector and its progeny HiResMnu to traditional neutrino detectors like NuTeV

Department News

Quantum Theory Group By Brett Altschul

Faculty members: Brett Altschul, Vladimir Gudkov, and Pawel Mazur

Graduate students

Alejandro Ferrero, Andres Sanabria, and Anton Kravchenko

Undergraduate students

Kathryn Metzger

This is an active time for the physics and astronomy department's particle theory group. This is especially true for the work of Professor Vladimir Gudkov, whose research focuses on understanding fundamental physics with neutrons. The next few years will be an especially exciting time for this field because experiments at the Spallation Neutron Source (SNS) should provide a tremendous amount of new and interesting data.

The SNS, located at the Oak Ridge National Laboratory in Tennessee, 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, which are split into up to 18 beams, to be used for different types of experiments. Some beam lines are complete, with operational instruments installed, while some are still in various stages of preparation.

Gudkov is involved with experiments that will use the SNS's Fundamental Neutron Physics Beam Line (FNPB), which started operating in 2008. While most of the beam lines will use neutrons as probes for studying other materials, the focus of the FNPB is on the neutrons themselves. For example, the beam line will produce large numbers of neutrons, whose lifetimes may be measured precisely. While neutrons bound in nuclei are generally stable, free neutrons decay with an average lifetime of about 880 seconds. However, there have been large discrepancies between different experiments measuring this lifetime, and the improved data the SNS can provide will be important to resolving this discrepancy.

Another intriguing possibility is the observation of a Neutron Electric Dipole Moment (NEDM) in the next generation of experiments, which would indicate a violation of Time-Reversal Invariance (TRI) not associated with the known CP violation in the standard model. The search for T violation has fundamental importance from several standpoints. An explanation of the baryon asymmetry of the universe, necessary for the existence of atomic nuclei, requires CP violation beyond the standard model. Assuming that CPT is a good symmetry of nature so that the violation of TRI implies the violation of CP symmetry, this new CP violation could be discovered in the next generation of NEDM searches if it is associated with new interactions at the TeV scale. Therefore, it will be clear evidence of manifestation of new physics.

As neutron physics enters this new era, Gudkov has received a new grant from the Department of Energy, which will support his efforts to better understand neutron decay, the NEDM, and other observables that may be studied at the

SNS. Precision measurements of these phenomena may provide new windows onto physics we don't yet understand.

Altschul studies some of the strangest forms that new physics could take. One exotic possibility that has gotten attention in the last decade is that "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. There are two main ways to search for changing "constants." One method is to make a precision laboratory measurement of some physical quantity, then remeasure it months, years, or decades later. Using extremely precise atomic clocks, researchers have monitored the characteristic frequencies of certain transitions in hydrogen and mercury atoms. The lack of any systematic change in these frequencies over the last five to 10 years indicates that the constants involved must have a fractional rate of change of one part in 10^{15} per year or less.

The other method of searching for variation in the fundamental constants is to compare data taken at the present time with evidence of interactions that happened thousands, millions, or billions of years ago. The light from very bright, very distant quasars has a characteristic spectrum, indicative of the elements present at the source. However, if the electron charge has changed since the light was emitted billions of years ago, these spectra would differ from the same spectra measured in the laboratory today. Although the precision with which the quasar spectra are known does not approach that of the laboratory data, the incredibly large time differences involved mean that the astrophysical bounds are comparable to what can be achieved entirely in the labs.

Altschul has been looking at how a changing value of the electron charge could affect the propagation of photons, even when those photons do not seem to be interacting with matter. The Heisenberg Uncertainty Principle dictates that energy conservation can be violated on very short time scales. A photon moving through the vacuum can change into a virtual electron-positron pair, which lasts for roughly 10–20 seconds before annihilating one another and re-creating the original photon. This "vacuum polarization" has small but observable effects. The rate of pair creation depends on the electron charge; if that charge is changing, new effects, such as a photon mass, could arise, with potentially observable consequences.

Professor Pawel Mazur has worked extensively on the physics of black holes. He is currently working with a student, studying the possible trajectories of objects orbiting rotating black holes. These orbits differ from conventional ones in several important ways. The satellites may zoom in and out, tracing out novel patterns, and the gravitomagnetic field, which, according to the general theory of relativity, generates all massive rotating objects, also affects them.

Introducing QRECT: A Revolutionary Classroom System

By Joseph E. Johnson

QRECT, a revolutionary classroom system that manages classroom data and learning assessments, is being used with a special Physics 201 section this fall. Developed by Dr. Joseph Johnson, professor of physics, each student uses a personal iTouch, iPhone, Netbook, or other Internet device to respond to frequent class questions from the instructor. The instructor's laptop allows the viewing and instant grading of questions from all students every few minutes, thus promoting one-on-one instruction and strong engagement. Attendance, class questions, demographic data, opinion polls, homework, and merit points are electronically graded and managed with grades e-mailed to students at the end of class. During exams, the instructor can monitor the response to each question by each student and student's grades are also sent by e-mail immediately after the class. In addition to reducing instructor information workload, and mandating engagement, the next most important feature is for the instructor to be able to instantly see student's incorrect responses, and thus to be able to immediately address misunderstandings and misconceptions in learning.

The system has 18 components, including self-correcting algorithms that use information theory to estimate optimal answers and to provide innovative metrics on question quality and value for assessment analysis. An innovative methodology for standards tracking in real time is being developed. One new component of the system utilizes pointing devices, including touch screens, to rapidly collect responses from preschool children who can touch a screen to respond to questions all the way to language training, military applications for rapid identification of domains of interest, and university anatomy courses. The innovative aspect here is the option of either instructor identified correct response domains or the definition of correct touch response domains based upon weighted expert user responses, thus providing for extremely rapid development of new image tests. The system is immediately applicable to differentiated learning, distance education, corporate training, and more advanced applications for team decision and analysis.

The QRECT system resides on a central Web server, and no software is loaded onto either the instructor's laptop or the student devices. Those who are interested can contact Dr. Johnson at 803-777-6431 or, preferably, by e-mail at jjohnson@sc.edu. Limited information is available at www.qrect.com. Formal registration and approval is required to use the system.

Updates from the Director of Undergraduate Studies

By Jeffrey Wilson

This fall, we have more than 80 students as declared physics majors, and our program continues to grow. We had 10 graduates this past academic year. Three students received academic awards last spring: Dominik Ralf Gothe won the College of Arts and Sciences Rising Senior Award for 2008–2009, Alexander Jacob Lesov was awarded the Nina and Frank Avignone Fellows Fund for 2008–2009, and Charles Samuel Peterson won the Rudy Jones Physics Award for 2008–2009.

Updates from the Director of Graduate Studies

This fall semester got off to a great start. Our graduate program remains strong and presently totals 46 students. This year, we welcomed seven new students to our graduate program from five countries (two from the United States, two from China, one from Lebanon, one from Saudi Arabia, and one from the Ukraine). We are pleased about the strength and diversity of our program.

In addition, our department awarded a total of 19 degrees within the last year. Our MS and Ph.D. graduates continue to find positions in private industry, government, and universities throughout the region and country.

While our students continue to excel, 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

Nathan Baltzell
Xurong Chen
Hossbach Hongxuan Liu
Joseph Meiring
Vladimir Montealegre
Michael Paolone
Gabriel Saracilla
Sohelia Gharanfoli
Todd Hossbach

Master of Science

Richard Foster
Brad Knaus
Christopher Kullenberg
Shakil Mohammed
Abraham Pernicka
Inti Sodemann
Jonathan Stenbeck
Isai Sundararaman
Vaibhav Tiwari
Legna Torres

Graduate Physics Program is Poised for Growth, Success

By Yaroslav Bazaliy

Graduate education is an extremely important component of a research university operation. This fall our department chair formed a committee charged with the task of a radical improvement of the graduate student experience at physics and astronomy (Ph.D. committee). As one of the six members of the new committee, I look forward to working on the development of the program.



Inti Sodemann at the Boulder Summer School on Condensed Matter Physics in July 2009

Here I would like to illustrate my view on the course of action that would attract bright applicants to the University of South Carolina physics program. As an example, I will use a success story of a recent master's student who graduated in 2009. Inti Sodemann entered the University in 2007. He was one of the students recruited to South Carolina by Professor Alonso Botero. Professor Botero personally knew the best students to talk to since he was working both at USC and at the National University of Colombia. Looking back, we can see clearly that he made a very good choice.

After arriving in Columbia, Inti did a couple of research rotations with Professor R.A. Webb and Professor A. Botero. In the summer of 2008 he joined my group and we started a pilot project on spin-transfer torques that bore some results in early fall. By October, we submitted an abstract to the 53rd Conference on Magnetism and Magnetic Materials, an influential forum of academic and industrial researchers in the field of magnetism. It was very important that Inti was able to attend the conference and present the paper in person. A conference trip is a great enthusiasm boost for a young researcher. Suffice it to say that another project we are currently finishing with Inti grew out of a conversation he had during this trip to Austin, Texas. The results reported at MMM comprised the master's thesis of Inti Sodemann, which he successfully defended in May 2009.

I tend to draw the following lesson from my experience in supervising Inti's master's work. Our department is on the right track in emphasizing the importance of recruiting efforts. Every graduate

program needs bright students, but not every program has the same probability of receiving their applications. Sad but true, getting good students will take much more effort here at USC than in a major Ivy League university. The good news is that it is not entirely impossible to recruit excellent students if they are approached individually and if a direct communication with a USC faculty member is established.

The students we should target are those who put extra value on the personal human contact with the representatives of their future graduate institution. These students have the same great physics education and research abilities, but are less adventurous in marketing themselves worldwide by applying to every big-name school. To find them, we would benefit from making it a tradition to encourage faculty members presenting our graduate program to prospective students on their visits to other institutions. This is already done on a case-by-case basis, but is not yet an institutionalized practice at the department.

Ideally, a successful recruitment of an outstanding student would constitute a substantial asset for a faculty member. By setting well-defined incentives associated with the recruiting activity and the quality of enrolled individuals, we can create a climate where faculty members would be interested in finding good prospective students in any field of specialization rather than only those students who can potentially join their own research group. Moreover, we should encourage and provide resources to current graduate students to search and identify potential good candidates for graduate studies at USC. First-year graduate students often have social contacts with younger generation students in their undergraduate institutions and can serve as an excellent source of information.

In summary, recruitment efforts can and will have a significant impact on the success of our graduate program and quality of students. These days, when sustainability and organic growth are emphasized in all fields of human activity, we may need to focus on growing our own population of graduate applicants and leave behind the practice of harvesting the applications from the mailbox.

Previous Graduates—Where Are They Now?

Nathan Baltzell graduated in spring 2009 with a Ph.D. in physics.

Xurong Chen graduated in fall 2008 with a Ph.D. in physics.

Soheila Gharanfoli graduated in summer 2009 with a Ph.D. in physics and has taken an instructor position at the Astronomy Center here at the University of South Carolina.

Robert Heaton graduated in spring 2007 with an MS in physics and is a project manager at the Space and Naval Warfare Systems Center (SPAWAR) in Charleston, S.C.

Todd Hossbach graduated in summer 2009 with a Ph.D. in physics and for the next two years will have a Pacific Northwest National Laboratory funded postdoctoral research fellowship to work at the University of Chicago on coherent neutrino scattering and direct dark matter searches.

Brad Knaus graduated in fall 2008 with an MS in physics and is working at the Space and Naval Warfare Systems Center (SPAWAR) in Charleston, S.C.

Chris Kullenberg graduated in summer 2009 with an MS in physics and is continuing research with our High-Energy Physics Group here at the University.

Hongxuan Liu graduated in fall 2008 with a Ph.D. in physics and is working part-time with our High-Energy Physics Group to complete some work.

Shakil Mohammed graduated in spring 2009 with an MS in physics and is continuing his graduate studies at the University of Texas at Austin.

Branton Monciffe graduated in summer 2007 with an MS in physics and is now working toward a Ph.D. in science and math education at Southern University in Baton Rouge, La.

Vladimir Montealegre graduated in summer 2008 with a Ph.D. in physics and has taken a postdoctoral position at the Memorial Sloan Kettering Cancer Center in New York City.

Abraham Pernicka graduated in spring 2009 with an MS in physics and has taken a position as a software engineer at IAVORS in Durham, N.C.

Inti Sodemann graduated in spring 2009 with an MS in physics and is continuing his graduate studies at the University of Texas at Austin.

Jonathan Stenbeck graduated in summer 2009 with an MS in physics and has taken a position as a medical physicist at South Carolina Oncology Associates in Columbia.

Isai Sundararaman graduated in 2008 with an MS in physics and is currently a medical physics resident at The Ohio State University Comprehensive Cancer Center—James Cancer Hospital and Solove Research Institute in Columbus, Ohio.

Vaibhav Tiwari graduated in spring 2009 with an MS in physics.

Legna Torres graduated in summer 2009 with an MS in physics and is continuing her graduate studies here at the University in the Department of Geological Sciences.

A Few Words from The Editor

Editing the *Quantum Leap* has been a great opportunity to find out more about the exciting work of my colleagues. I have greatly enjoyed putting this issue together with the help of our entire faculty and Ms. Mary Papp. Mary and I would like to thank everyone who contributed to this newsletter—your participation has made it possible for us to include reports on almost all aspects of the vibrant research activities that go on in our department.

Indeed, the wide range of scientific endeavors here at the University is amazing: the study of the atomic nucleus, quarks, neutrinos, the fundamental constants, condensed matter, superconductivity, gravitation, dark matter, quasars, and galaxies, to name a few of our passions. On the applied side, we have an equally broad array of activities, such as spintronics, nanoelectronics, nanomagnetism, bio-nano materials, medical physics, and psychoacoustics. We offer competitive research opportunities in these areas both at national facilities and here on site. Of course our research involves not just the faculty, but also our wonderful graduate and undergraduate students. The training of young minds and preparing the next generation of the scientific workforce is one of the most fun and rewarding missions of our department.

Throughout history, the pursuit of physics and astronomy has led to groundbreaking technological advances and direct benefits to the economy: the discovery of the new world, the industrial revolution, and the information revolution all owe their roots to advances in physics and astronomy. Our research brings cutting-edge technology and educational resources to South Carolina and also makes us an important agent of change in advancing South Carolina to the next level scientifically and economically.

In tumultuous socioeconomic times such as these, there is something reassuring about the wonders and vastness of nature. We hope our readers have enjoyed a glimpse into the mysteries of our Universe on this quick tour of our scientific explorations on all scales from atto-meters to Giga-light-years.

I express my best wishes to all of our students, alumni, faculty, and staff, and I sincerely thank all friends of the department for the generous support they have provided us over the years.

—Varsha P. Kulkarni

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Awards

Graduate Students



Eric Graham was the recipient of the 2009 Graduate Student Teaching Award.



Carlos Martinez was the recipient of the 2009 Graduate Student Research Award.

Undergraduate Students

Dominik Ralf Gothe received the College of Arts and Sciences Rising Senior in Physics Scholarship Award for 2008–2009.

Alexander Jacob Lesov was the recipient of the Nina and Frank Avignone Fellows Fund for 2008–2009.

Charles Samuel Peterson was the recipient of the Rudy Jones Physics Award.

A Time to Celebrate



Pictured is the physics and astronomy department chair Professor Chaden Djalali (center), along with two faculty members who received tenure and promotion in 2008–2009 from College of Arts and Sciences dean Mary Anne Fitzpatrick. At the ceremony, Professor Steffen Strauch (to the left of Professor Djalali) received tenure as an associate professor, while Professor Vladimir Gudkov (to the right of Professor Djalali) received tenure and promotion to professor. Also sharing this happy moment were Professor Yordanka Ilieva (far left) and Mrs. Gudkov (far right).