Quantum Leap
University of South Carolina
Department of Physics and Astronomy
Fall 2006

Crawford Group Moves into Renovated Labs

The Crawford Group moved into two newly renovated laboratories in the Sumwalt NanoCenter at the beginning of February 2006. With conducting floors and expandable overhead bus bars for electrical distribution, these labs are well-equipped for experimental nanoscale research. The Crawford Group is currently made up of a research professor, Dr. Anjan Barman, and three graduate students: Robert Heaton, MS candidate, fall 2006; Brad Knaus, Ph.D. candidate; and Longfei Ye, Ph.D. candidate.


Thomas Crawford

Dr. Barman came from the University of California, Santa Cruz, where he was a postdoctoral fellow working on time-resolved studies of magnetodynamics. Barman is funded by Seagate Technology LLC, Crawford's previous employer, to continue studies of time-resolved magnetization dynamics on magnetic materials of interest for future data storage technologies. Barman is constructing a picosecond-resolution pulse shaper for controlling the temporal shape of a pulse in the <100 ps timescale for customized studies of magnetodynamics. These studies are critical for enabling magnetic data storage, magnetoresistive random access memory (MRAM), and other magnetic sensor technologies to perform in the microwave frequency range where the component materials display ferromagnetic resonance. In collaboration with the Webb group and Dr. Mark Covington at Seagate Research, Longfei Ye is studying the stability of magnetodynamics excited by electron current in nanoscale magnetic multilayers through an effect known as spin momentum transfer. In these structures, a DC electric current can excite continuous, undamped, precession of the magnetization in the free magnetic layer. Ye is focusing on the effect of noise and dynamic disruptions on the stability of these precessional dynamics.

In addition to fundamental studies of dynamics in nano-patterned magnetic materials and devices, the Crawford Group is working on several other topics in magnetism, ranging from applied nanoscience to the physics of new magnetic materials. Robert Heaton has constructed a scanning probe microscope, which uses a magnetic recording head as the probe, and can also perform magnetic recording. This instrument will be used to record custom patterns in magnetic media (such as the dibits in the lower half of the image) and use the force exerted by the nanoscale stray fields of these transitions to program the assembly of magnetic nanostructures into larger devices. The group has an ongoing collaboration with Dr. Catherine Murphy's group in the USC chemistry and biochemistry department to assemble magnetically coated nanostructures, and it's looking to establish other collaborations as well.

At the forefront of the search for novel magnetic materials, the Crawford Group is beginning a study of a fascinating magnetic material: magnetic-Au. When capped with chemisorbed thiol-based compounds, the surface of Au films and nanoparticles have exhibited enormous para/ferro- (it's not clear which) magnetic moments (up to 100 Bohr magnetons), which remain at room temperature in 2 nm diameter Au particles, meaning the anisotropy energy is larger than what is seen in SmCo5, the largest anisotropy permanent magnet material. Graduate student Brad Knaus will be fabricating Au-thiol structures for magnetic measurements, as well as incorporating these Au-thiol bilayers into conventional magnetoelectronic structures as a means to identify the fundamental origins of the magnetism in these bilayer structures. Using the new (Webb/Crawford shared) Quantum Design Physical Property Measurement System AC/DC magneto-

see Crawford Group, pg. 3

UNIVERSITY OF SOUTH CAROLINA

From the Chair

A Message from the Chair

Chaden Djalali

We have decided to send out this small update of *Quantum Leap* to inform our alumni and friends about developments in our department. One big change is the retirement of five of the department's faculty and one staff member. We are deeply indebted to Yakir Aharonov, Chi-Kwan Au, Jim Knight, Barry Preedom, and Gary Crawley for their enormous contributions to the research, teaching, and daily life of the department. We are also thankful to Lynn Waters, who recently retired after 27 years of service to USC. It is hard to do justice to the contributions these persons have made. I will just refer you to the short summary write-ups in this issue of *Quantum Leap* for more information. The faculty joins me in wishing them all a long, healthy, and fruitful retirement. We hope to see them around and will welcome and appreciate any future involvement they have with the department.

Extramural funding is an important requirement for any excellent physics department. We are proud that the physics department has had significant successes in competing for external grant support in the last year. Many individual investigators as well as large groups have secured funding for supporting their world-class, cutting-edge research. We have successfully attracted strong graduate students interested in the research carried out at USC.

The physics department is happy to report that Dr. Yaroslaw Bazaliy has joined the faculty as a condensed matter theorist. Bazaliy received his Ph.D. in 2000 at Stanford University and comes to us from the IBM Almaden Research Center in San Jose, Calif., where he was a postdoctorial fellow since 2004. From 2000 to 2004, he was a postdoctoral fellow at Argonne National Laboratory working on a wide variety of topics in magnetism for both fundamental and applied research purposes. Before coming to the United States and after his master's degree, he had four years of theoretical training at the prestigious Kapitza Institute for Physical Problems. He is a well-trained theorist with expertise in a wide variety of techniques that he has used to solve important problems in quantum phase transitions, high Tc superconductivity, quantum magnetism, and superconductor-ferromagnet proximity effects. Some of his applied physics work centers on semiconductor spintronic applications and devices that use spin-polarized current for new functionality in the computer industry. He has also worked on the theory of how bacteria move as well as new models of how biological cells move. He has a strong track record of collaborating with both experimentalists and theoreticians, and we believe he will continue to do so in the future. We are sure that he will be able to start collaborations with some of our USC colleagues in the Nano-Center, chemistry, and engineering as well as within the Department of Physics and Astronomy.

External donations from our alumni and friends have and continue to help us maintain programs that improve the quality of life for students and faculty in the department. We thank everyone who has donated to the physics department, and we assure you that your support has made an enormous difference.

Nuclear Experimental Group

The experimental intermediate energy group presently consists of four experimentalists, two postdoctoral research associates, and eight graduate students. Group research involves the study of nuclei and nucleons with electromagnetic probes. We are also leading programs in baryon spectroscopy and the study in nuclear-medium modifications of hadrons. The research is carried out at the Thomas Jefferson National Laboratory (JLab).

This fall we started our latest experiment, which tries to determined whether or not nucleons change inside a nucleus. Nuclear physicists have wondered whether nucleons change their properties when bound in a nucleus. This possibility was considered seriously with the discovery of the "nuclear EMC effect" some twenty years ago, in which electron scattering from quarks inside a nucleus was discovered to differ from electron scattering from quarks in a free nucleon. The USC group is leading experiment E03-104 at JLab. Polarization-transfer data from this experiment allow us to compare the properties of protons bound inside the Helium-4 nucleus with those of a free proton. Our earlier data suggests it may be more economical to describe nuclei in terms of nucleons, which differ from free nucleons. This is the second indication that a nucleus is not merely a set of bound nucleons.

Opportunities in experimental physics and research

Gary Blanpied

While the basic curriculum in theoretical physics has remained the same, we have recently tried to increase the opportunities in experimental physics and research. All incoming students now take a laboratory course, PHYS 199, which we first offered in fall 2005. In the course PHYS 499 students get academic credit rather than pay for working with a professor on a research project. After years of discussions we finally made the PHYS 512 condensed matter course a 4-hour course with a laboratory. We have been trying to use student laboratory fees to keep the 100- and 200-level physics laboratory and astronomy laboratory equipment functional while adding computers and projectors into each lab and classroom. When the college taxed the lab fees and set up yet another college committee to look at proposals, we aggressively applied with seven different proposals, which were all funded at a total of about $200,000. We received more than $100,000 for the condensed matter laboratory, which is being developed by Thomas Crawford. He earlier received money from the computer committee to buy seven computer-based systems for the electronics laboratory course (PHYS 509). Robert Sproul and Richard Hoskins obtained equipment and computers for the 100- and 200-level labs, and Carl Rosenfeld obtained ceiling-mounted projectors for two classrooms.

I obtained funds to buy five large scintillation-based detectors from Teachspin for about $25,000. These will be utilized for demonstrating relativity and for obtaining data on the sea-level cosmic ray flux and the muon lifetime. The rate of positive and negative muons, electrons, and positrons is about 7/s. The electronics are set up to look for a second particle for 20 microseconds after each event. The lifetime of stopped muons is 2.2 microseconds. They decay to two neutrinos, which escape detection, and an electron (or positron) that comes out with up to 40 MeV. The rate of stopped muons is about 1 per minute at sea level. Students in PHYS 308 are using the detectors in October 2006.

Alumni News

Tannis (Smith) Shipley, who received her BS in 1986, has recently gone back to school in North Carolina. Her husband, Bill, is a medical doctor, and she has three boys, Preston (13), Nathan (9), and Ryan (6). She is in the seminary at Gardner Webb. She finds that there is great respect for her training in physics, and the analytical thinking skills she acquired through physics have served her well in the academic world of biblical studies. She has a unique view, which she is only now learning how to use to its fullest. She would very much like to go back to teaching as an adjunct in biblical studies and physics.

Crawford Group continued from pg. 1

transport and vibrating sample magnetometer in the USC NanoCenter, Knaus will attempt to demonstrate magnetoresistance in materials structures containing Au-thiol structures. To measure the magnetization specifically at the Au-thiol interface, the group has a femtosecond Ti:sapphire laser to perform interface sensitive second-harmonic magneto-optic Kerr effect (SH-MOKE), to measure the magnetization as a function of thiol and Au properties. If one can understand the underlying physics, then perhaps we can discover how to modify and optimize the magnetic properties of this material. On this project, the group is collaborating with Murphy to selectively cap the ends of Murphy group Au nanorods with thiols and determine their magnetic properties, as well as with Dr. Chad Leverette, at USC Aiken, a spectroscopist who is interested in studying the surface properties of nanostructured noble metals with adsorbed thiols.

Finally, the Crawford Group is interested in picoscale metrology for enabling nanotechnology. To this end, the group has a molecular imaging (now owned by Agilent Technologies) scanning probe microscope, which can perform scanning tunneling microscopy, atomic force microscopy, and a host of derivative probe microscopies. The group is in the process of establishing a number of collaborations with other groups to develop new measurement technologies to benefit a wide range of fields, from emerging nanotechnologies to medical diagnosis and treatment. "With stretch goals like trying to localize the measurement of magnetic field to less than 0.5 nm, our focus is unique in that we are trying to develop measurements that can be used not only for discovery but eventually for manufacturing new nanotechnologies," says Crawford, who did postdoctoral work at NIST's Boulder Laboratory on new metrologies for magnetic data storage, and spent six and a half years developing new measurements for characterizing advanced magnetic recording components at Seagate Technologies Research Division.

Crawford Group (L-R) front: Longfei Ye and Rob Heaton; back: Anjan Barman, Thomas Crawford, and Brad Knaus

Retirements in 2006

Yakir Aharonov

Yakir Aharonov, endowed professor, retires after a close association with the University of South Carolina for more than 40 years. He came to the USC campus for the first visit in summer 1965 at the invitation of Professor Edward Lerner. They met while Lerner was on sabbatical leave at Brandeis University. A few years later he held a position in which he was at USC every summer and a full semester every third year. In the early 1980s, he was granted a tenured endowed professorship that divided his time between USC and Tel Aviv University. In 1980 the department was awarded a National Science Foundation EPSCoR Grant that contained funding for a Summer Institute for the Foundations of Quantum Theory, led by Dr. Aharonov. That institute brought visitors from many countries during the summer months.

Yakir Aharonov is also distinguished professor emeritus of Tel Aviv University. He is truly an internationally renowned physicist, famous for his seminal contributions to the foundations of quantum theory, including the Aharonov-Bohm effect, which have influenced many fields of physics and opened the new field of mesoscopic physics. He has won numerous prizes, including the Wolf Prize in 1998, the Hewlett-Packard Europhysics Prize in 1995, the Elliott Cresson Medal of the Franklyn Institute in 1991, and the Israel National Prize in 1989. He is a member of the U.S. National Academy of Science and the National Academy of Science of Israel. He owns a house in Columbia, S.C., and his colleagues hope that he will continue to visit USC.

Barry Preedom

June 30, 2006, was Professor Barry Preedom's last day at USC. During his final years at USC he was associate dean, first in the College of Science and Mathematics and then in the new College of Arts and Sciences.

Barry joined the USC faculty in 1970 and soon obtained a research grant to work at the Los Alamos Meson Facility (LAMPF). Over the years he built a strong research group in nuclear physics funded by the National Science Foundation (NSF). In 1979 Barry was instrumental in recruiting Professor Gary Blanpied to the USC faculty, thereby increasing the local nuclear research effort. Today there are four faculty members in the Nuclear Experimental Group and two faculty members in the Nuclear Theory Group. Both research groups are internationally well-known and funded by the NSF and have had several research associates and many students over the years. We wish Barry the best in his retirement. We know he will keep in touch with the very active research groups he founded at USC.

James M. Knight

One of the most versatile theoretical researchers and teachers, James (Jim) Knight, retired on June 30, 2006, after 41 years in our department. Although he has moved to the 4th floor, he has continued most of his activity in the department. The students are thankful that he has agreed to continue teaching the modern physics sequence, PHYS 501–502, this year. He has worked in many areas of physics research and has recently worked with Milind Kunchur on topics in superconductivity, including spin vortices. He is also working with James Stapleton, a senior physics major interested in theoretical physics. In the 1970s he worked with Ed Lerner and Yakir Aharonov on many theoretical physics topics. In the 1980s he worked with Horacio Farach, Charlie Poole, and Rick Creswick on condensed matter topics such as an antiferromagnetic Ising Model and evidence for an incommensurate phase in ESR measurements.

The graduate courses that he taught included Quantum Mechanics, Classical Electrodynamics, Statistical Mechanics, Classical Mechanics, Advanced Quantum Mechanics, Topics in Theoretical Physics: Chaos, and Topics in Theoretical Physics: Quantum Optics, while the undergraduate courses included Essentials of Physics (introductory engineering course), Intermediate Classical Physics (first sequence for physics majors), Solid State Physics, Advanced Laboratory: Solid State, Modern Physics, Classical Mechanics, Electrodynamics, and Advanced Optics.

His service to our department, college, and university has been extensive, including many committees, service as interim chair, and search committees for both our dean and for provost.

Chi-Kwan Au

Chi-Kwan Au retired on May 16, 2006, after 31 years on the faculty and moved this summer to Palo Alto, Calif., near his children. With predoctoral and postdoctoral terms at Columbia University, the University of Illinois, and Yale University, Au brought deep dedication to physics and a thorough grasp of principle to his work at the University of South Carolina. His students will remember the high standards he set in his classes.

Au worked on many areas of quantum electrodynamics and atomic physics during his tenure as a faculty member. In his early years, he worked on multipole effects in hydrogenic atoms and developed a new form of perturbation theory with Yakir Aharonov. Later, he turned his attention to the long-range interactions between atoms, the van der Waals force, and the Casimir effect. He maintained external collaborations with Gerald Feinberg at Columbia University and also by sabbatical visits to the Institute for Theoretical Physics at Santa Barbara, two universities in Hong Kong, and the Harvard-Smithsonian Institute for Astrophysics. His published work comprises 78 papers in refereed journals. He was elected a fellow of the American Physical Society in 1990.

He served on departmental committees with efficiency and a sense of responsibility. Au also served the University in several capacities, including faculty advisor to the USC Hong Kong Chinese Student's Association and the USC Asian American Association.

He was a trusted faculty colleague and an informal advisor to many students. We celebrate his years at the University.

Gerald M. Crawley

After a long and distinguished career, Dr. Crawley retired from USC on August 16, 2006. Crawley received his Ph.D. in Physics from Princeton University in 1965. He is internationally known for outstanding con-

tributions in experimental nuclear physics. Crawley was a professor at the Michigan State University from 1974 until 1988. He served as dean of the Graduate School at Michigan State from 1988 until 1994, when he came to USC as dean of the College of Science and Mathematics. He is a fellow of the American Physical Society and has served as chair of the Division of Nuclear Physics. He is currently serving as head of the Frontiers of Engineering and Science Directorate of the Ireland Science Foundation.

Lynn Waters

Lynn Waters retired after more than 27 years with the department. Both Dr. Mike Schuette and Dr. Frank Avignone conducted Lynn's original interview. She served as administrative assistant to four chairs: Dr. Frank T. Avignone III, Dr. James Knight (interim chair), Dr. Fred Myhrer, and Dr. Chaden Djalali. In addition to her administrative duties, on occasion Lynn has done the work of the travel secretary, the graduate student secretary, and the business manager. Those of us who worked with her for so many years will miss Lynn.

The Spallation Neutron Source

Professor Vladimir Gudkov, who is associated with Oak Ridge National Lab as Distinguished Visiting Scientist and the leading theorist for the Fundamental Neutron Physics Project at the Spallation Neutron Source (SNS) at Oak Ridge, reports that on April 28, 2006, SNS successfully produced its first pulse of neutrons, demonstrating that the most powerful neutron facility in the world works. This opens research opportunities in many fields, including neutron physics and neutrino astrophysics. One of the projects at the SNS is to search for time-invariance violation by measuring the neutron electric dipole moment (EDM). If EDM is nonzero, then time-invariance is violated.

Nuclear Theory Group

We welcome our new research associate, Dr. Anders Gårdestig, who joined us in December 2005. He received his Ph.D. from Uppsala University in Sweden and worked at UCLA, Indiana University, and Ohio University before coming to South Carolina. Anders is greatly reinforcing our research activities on the nuclear physics application of effective field theory (chiral perturbation theory). This is a comprehensive project aiming to provide first-principle descriptions of nuclear electroweak nuclear reactions, and its results have far-reaching ramifications in our understanding of various astrophysical processes such as nuclear burning in stars and supernova explosions.

Our two students, Barbara Szczerbinska and Ivan Danchev, defended their Ph.D. thesis last summer. This fall semester Barbara was hired as a tenure track assistant professor at South Dakota State University in Madison, S.D., and Ivan is now a research associate at Vanderbilt University.

Astronomy Group

Dr. Christina Lacey worked with her undergraduate student, Jon Stenbeck, and two graduate students, Leila Mizouni and Sara Schultz, on observations that were taken at the world-class radio telescope the Very Large Array, located in Socorro, N.M. Stenbeck measured the brightness of several radio supernovae at different epochs. Mizouni contributed to a project with Lacey and Dr. W.M. Goss of the National Radio Astronomy Observatories on the 30-year decline in radio emission of a young, ultra-luminous supernova remnant located in a nearby galaxy. Schultz worked on her master's thesis: an investigation of a rare, ultra-compact HII region, which is where new stars form. Dr. Lacey also worked with collaborators Dr. Tom Pannuti of Morehead State and Dr. Eric Schlegal of the University of Texas, San Antonio, on Chandra X-ray observations of supernova remnants in nearby galaxies.

Professor Varsha Kulkarni, graduate students, and collaborators continued research in extragalactic astronomy and cosmology using optical, infrared, ultraviolet, and X-ray facilities. Our work is funded by the NSF and NASA, including new grants received from the NSF and NASA Spitzer Space Telescope. Our research resulted in 8 refereed and 4 unrefereed publications within the past academic year, while 3 more submitted papers are currently being refereed. Observations were obtained with the Very Large Telescope (VLT) and the Magellan Clay Telescope in Chile, the Gemini-N and Keck telescopes in Hawaii, the Apache Point Observatory (APO) in New Mexico, the Chandra X-ray Observatory, and the Spitzer Space Telescope. With VLT, we discovered a galaxy that was 4 times as metal-rich as the Sun 6.3 billion years ago, which led to a press release by European Southern Observatory and a short article in the magazine *New Scientist* in February 2006. Our goals are to measure element abundances, sizes, and star formation rates in galaxies producing low and intermediate-redshift quasar absorbers and their implications for galaxy evolution over the past ~10 billion years.

Graduate student Soheila Gharanfoli continued her Ph.D. thesis work on high-resolution imaging and spectroscopic confirmation of quasar absorber galaxies using Keck. Graduate student Joseph Meiring defended his Ph.D. thesis proposal in fall 2005. He has been working on measuring element abundances in the absorbers with VLT and Magellan. Graduate students Lorrie Straka and Karthikeyan Bhaskaran are working on emission-line imaging of galaxies in quasar fields. Ten conference presentations were given by Professor Kulkarni and graduate students Gharanfoli and Meiring at the American Astronomical Society meeting in Washington, D.C., in January 2006, the South Carolina Academy of Sciences meeting in March of 2006, and the Meeting of Astronomers in South Carolina in April 2006.

Condensed Matter Group

Besides Thomas Crawford (see earlier article), there are four other experimentalists (Richard Webb, Timir Datta, Horacio Farach, and Milind Kunchur) and three theorists (Yaroslaw Bazaliy, Richard Creswick, and James Knight) working in the area of condensed-matter physics. Bazaliy was hired recently and will begin working at USC in fall 2007 in the area of magnetism.

Distinguished University Professor Richard Webb's group works in the area of low-temperature quantum electronics. His group consists of himself, postdoctoral student Samir Garazon, and graduate student Longfei Ye. The focus of their group is basic research in nanoelectronics, which has opened up a realm of possibilities for discovering new physical phenomena as well as producing new hybrid links for greater functionality in computing and magnetic storage industries. By locally exploiting and controlling quantum coherent couplings and interfaces between one or more nearby atoms, molecules, or other complex structures, it is hoped that new optical and electronic properties can be produced and controlled. The potential for harnessing the electron spin for novel and exciting applications has fueled a tremendous growth in the field of spintronics and led to new devices based on the giant magneto-resistance effect and spin-polarized transistors. It has long been hoped that new nanoscale devices that make use of quantum coherence and entanglement of the orbital and/or spin parts of the electron wavefunction can be developed. Since the electron spin is a two-level quantum system, we are currently attempting to use two coupled spins as the basic building block of a quantum computer. This group uses electron beam lithography and a variety of material deposition techniques to create quantum devices in metallic and semiconducting structures with feature sizes ranging from 20 nm to many microns. The group makes one-dimensional wires, nanopillars, quantum point contacts and zero dimensional quantum dots and study their properties in magnetic fields as high as 16 tesla, frequencies as high as 26 GHz, and temperatures as low as 3 mK. Current efforts are oriented toward: producing entangled electron spin states in coupled quantum dots, investigation of charge and spin transport in spin valve structures and opto-electronic properties of GaN and SiC nanowires, and the measurement of electron transport in a time scale shorter than the phase coherence time of individual electrons.

Professor Milind N. Kunchur and Emeritus Professor James M. Knight (see "Retirements in 2006," pg. 4) work on exploring new phenomena in superconductivity that unfold at extreme electric fields and power densities. This research program has led to the discovery of new effects such as the hot-electron vortex instability and a new third category of superconducting behavior that had not been observed before. Besides their work on superconductivity, this group is also involved in interdisciplinary research in acoustics and hearing perception. In recent work previous thresholds on the temporal resolution of hearing were broken, generating much controversy in the psychoacoustics and neurophysiology fields. A graduate student, Gabriel Saracila, and undergraduate students Charles Peterson and James Stapleton are working in this group.

Distinguished Emeritus Professor Horacio Farach has returned to his native Argentina but continues to collaborate on several projects at USC, including second editions of "The Physics Handbook" (with Charlie Poole), "Superconductivity" (with Poole, Creswick, and Prozorov), and a compilation of problems taken from the USC Admission to Candidacy exam (Poole and Creswick). He and Professor Creswick are also active members of the Cuore/Curocino team together with Professors Avignone and Rosenfeld, testing candidate materials for bolometers using ESR. The graduate students working with this group are Baowei Liu, Yeuncheol Jeong, and Roger Crazy Wolf.

Foundation Group

During the last year we had several visitors and collaborators in our group before and during the 2006 Quantum Theory Summer Institute.

Dr. George Chapline (Lawrence Livermore National Laboratory), who has been collaborating with Dr. Pawel Mazur for the past several years, came for a working visit in April 2006. He and Mazur worked on the cosmological implications of their superfluid theory of space-time. They came up with a model of a finite-sized, slowly spinning Universe, which far from its boundary and at early times is dominated by a vacuum energy density. Our model resolves the initial cosmological singularity problem of the hot Big Bang model. The paper Mazur wrote with Chapline describing their cosmological model has attracted some attention. A cover page featured article about the work of Chapline and Mazur, "Is space-time actually a superfluid?" authored by Marcus Chown, appeared in *New Scientist*, issue 2555, on June 9, 2006.

As mentioned in the Quantum Theory Summer Institute report, Mazur described to the other participants his recent work on what has became known as an "emergent gravitation." Although Mazur wrote his first papers on the subject of a constituent model of gravitation about a decade ago, it was only in the past 2–3 years that the area of "emergent gravitation" has acquired an interdisciplinary character, and as a result it started to attract a growing number of researchers. Mazur has been invited to co-organize the first workshop on emergent gravitation in the Lorentz Center at Leiden University, Netherlands, in August 2007.

High Energy Physics Group

The BaBar experiment at the Stanford Linear Accelerator and the ATLAS experiment at CERN in Geneva, Switzerland

The BaBar experiment continues to do very well and recently concluded Run 5 of data taking. Around 150/fb of data were recorded by BABAR. The day before the run concluded, the accelerator and experiment set numerous new records: a peak luminosity record, a single shift record, a 30-day record, and a record of more than 100/fb delivered in FY06 (DOE milestone). During summer 2006, we have been busy with the installation of the LST detector upgrade for muons, in which two people from South Carolina planned to participate: graduate student Ryan White and postdoctoral student Woochun Park. A new graduate student, Arjun Trivedi, is starting up an analysis on BaBar and is making good progress. Graduate students Hongxuan Liu and Xurong Chen are close to finishing their thesis work, which should be published in spring of next year.

In the meantime, the BaBar group is already thinking of life after BaBar ends data-taking in 2008. Professor Purohit, taking advantage of a sabbatical, visited CERN in Geneva, Switzerland, during August and September 2006 to participate in the ATLAS experiment and worked on an upgrade proposal for the CSC detectors. Along with Professor Wilson, Park, and possibly also Professor Petti, he plans to steadily increase involvement in ATLAS. ATLAS and CMS are the main experiments at the new CERN Large Hadron Collider (LHC), soon to be the highest energy particle accelerator in the world. The energies of 14 TeV should be sufficient to find the famous Higgs particle and likely also high enough to confirm or quash many fanciful theories about matter: supersymmetry, extra dimensions of space-time, gravitons, and others. Our physics department will be a part of this historic effort.

The neutrino "oscillation" research by the MINOS collaboration

Notwithstanding continuing technical difficulty with the leaky horn, the MINOS collaboration continued vigorous data collection until Fermilab halted accelerator operations in February 2006 for maintenance and upgrades. Operation resumed in late May, and MINOS is once again collecting data.

The collaboration made its first public presentation of results from the data of the preceding twelve months at a colloquium at Fermilab on March 23, 2006. Fermilab Public Relations followed up with a news release that received considerable coverage in the public media. Our own Professor Sanjib Mishra gave a reprise of the results at USC on April 14.

In essence MINOS confirms that neutrinos leaving Fermilab (located near Chicago) with muon-flavor metamorphose (oscillate) to electron- or tau-flavor during the two-millisecond trip to the Far Detector located in Northern Minnesota. The MINOS determinations of the strength and the period of the neutrino-oscillation, though not yet very precise, are quite close to the values found by Super-Kamiokande using neutrinos produced by cosmic rays in the upper atmosphere. The MINOS collaboration has been showing these results at 2006 summer conferences, and it has submitted a paper for publication in *Physical Review Letters.*

Visiting Professor Alonso Botero

For the second year Professor Alonso Botero of the Universidad de los Andes, Bogotá, Colombia, is visiting USC during the fall semester to do research and to teach a graduate course in classical mechanics.

His research is on quantum information theory and the foundations of quantum mechanics. Currently, he is doing research on multipartite quantum entanglement in many-body systems (Spin chains, etc.), on measures of multipartite entanglement, and on several aspects of quantum measurement theory connected to weak measurements and weak values, pursuing ideas originally proposed by Professor Yakir Aharonov.

The Quantum Theory Summer Institute 2006

The 2006 Quantum Theory Summer Institute attracted participants from several countries. Apart from Professor Shmuel Nussinov, who spends three months at USC every year, and Professors Yakir Aharonov and Pawel Mazur, we had the following participants: Professors Alonso Botero, Universidad de los Andes, Bogotá, Colombia; Benni Reznik, Tel Aviv University, Israel; Sandu Popescu, University of Bristol, U.K.; and Aharon Casher, Tel Aviv University, Israel.

Since the doors to their offices were at times wide open, one could hear from afar lively discussions taking place in front of the blackboards. The following is some of the topics discussed: Botero and Reznik have an ongoing project on aspects of quantum entanglement; Aharonov, Botero, and Popescu initiated a study of a possible new lower bound on the time required for a quantum system brought in contact with a "heat bath" to reach thermal equilibrium.

Dr. Nussinov worked on SU(3) selection rules for heavy quarkonia decays into even/odd numbers of pseudo-scalar mesons and on the field theoretic consistency of a new dark matter scenario.

Dr. Casher acted as a sounding board, providing advice and at times criticism on most of the above-mentioned topics. In addition, he continued work on the possibility that two and higher loop regularization is likely to break Super-Symmetry. If correct, this research will have monumental consequences in both theoretical and experimental high-energy physics.

Dr. Mazur described to other participants of the institute his recent work on what has became known as an "emergent gravitation" (see "Foundation Group," pg. 6).

Particle Astrophysics Group

Faculty: Frank T. Avignone, Richard Creswick, Horacio Farach, and Carl Rosenfeld; Postdoctoral Research Associate: Iulian Bandac; Graduate Students: George King, Todd Hossbach, Carlos Martinez, and Leila Mizouni

Particle astrophysics is a recent outgrowth of a marriage between particle physics and astrophysics. The University of South Carolina group was one of the first in the field, having performed the first terrestrial search for the Cold Dark Matter (CDM). The gravitational effects of the CDM on the velocity distribution of stars in spiral galaxies was discovered by Fritz Zwicki in 1933. In 1985, the USC group, inspired by astrophysicists at Max Planck Institute in Munich, converted their early ultra low background experiment in the Homestake gold mine to search for an elementary particle form of CDM. The data from the first experiment was able to eliminate Dirac neutrinos as a major component of the CDM. Since those early experiments, these searches have become popular throughout the world, with significant improvements in techniques.

The group played a leadership role in searches for axions from the sun. Axions are elementary particles predicted by the theory of Peccei and Quinn to avoid possible charge-parity (CP) symmetry violation in the quantum chromodynamics vacuum. The experiments were based on the theory, developed by members of the USC group, of coherent Bragg-conversion of the axions to photons in single crystals, a technique later adopted by groups in Europe and Russia.

Recently, the USC group has been concentrating on ultra low background searches for the exotic neutrino less nuclear double-beta decay. This process can only occur in the case that neutrinos are their own antiparticles (Majorana particles), and only if neutrinos have mass. Recent neutrino oscillation experiments established that neutrinos do indeed have mass, but these experiments cannot measure the absolute values, only neutrino mass differences. Accordingly, a direct observation and measurement of the half-life would determine the absolute mass scale of all three of the neutrino "flavors." The group was involved in the CUORICINO double-beta decay experiment in the Gran Sasso Laboratory in Assergi, Italy from its beginning. This experiment has established a lower bound on the half-life of tellurium-130 of 2.4 X 1024 years. This experiment continues, and the group is participating in the development in the expanded version of the 42 kg CUORICINO experiment, namely, the 760 kg CUORE experiment. The group also was instrumental in the establishment of the germanium-76, double-beta decay research proposal called Majorana. This would be a great expansion of the completed International Germanium Experiment (IGEX), led by the USC group.

The group has been supported by grants from the National Science Foundation for more than 25 years, and it enables members to travel and work in Italy and to travel in the United States to participate in Majorana.

Quantum Leap

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

Telephone: 803-777-4121
Fax: 803-777-3065
E-mail: waters@mail.psc.sc.edu
www.physics.sc.edu/

Chair:
Chaden Djalali
Director of Graduate Studies:
David Tedeschi
Director of Undergraduate Studies:
Gary S. Blanpied

Editors:
Fred Myhrer
Mary C. Papp