Quantum Leap

University of South Carolina
Department of Physics and Astronomy

Fall 2008

In with the New

Yordanka Ilieva

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Yordanka Ilieva received her doctoral degree in nuclear physics from the Bulgarian Academy of Sciences in 2001 after defending her thesis "Simultaneous measurement of the reactions $pd \to {}^3He\pi^0$ and $pd \to {}^3He\pi^+$ in the threshold-resonance transition region." Before joining the Experimental Nuclear Physics Group in the department, Yordanka held an assistant research professor position at George Washington University, where she worked on experiments probing light nuclei with real photon beams.

Yordanka says, "My research focuses on studying nuclear dynamics at intermediate energies. The understanding of nucleon and nuclear structure, and the development of the theory of the strong interaction, the quantum chromodynamics (QCD), is central to modern physics research. We can probe strongly interacting objects over many distance scales by varying the resolution—energy—of the beam. We already know that the fundamental constituents of the nucleon—the quarks and the gluons—are confined and cannot be liberated and that at large distances they interact extremely strongly with each other. We also understand qualitatively that the mechanism of quark confinement gives rise to the properties of hadrons. Describing quark confinement quantitatively, however, has been a challenge. Tackling this problem requires focused effort both by experimental and theoretical nuclear physics.

"I think light nuclei are excellent mini-laboratories to study the production and propagation of hadrons in nuclear matter. Exclusive nuclear reactions on light nuclei provide access to small interaction scales and, therefore, sensitivity to short-range dynamical effects such as nucleon-nucleon correlations, hidden color, or color transparency. With my research I have been addressing questions as how does the nucleon-nucleon interaction change when the distance between the nucleons changes? How does the transition from long-distance scales to short-distance scales happen? And how does the nucleon substructure give rise to nuclear properties? All these are related to understanding the properties of the strong interaction and the development of QCD. And the latter is of vital importance to understanding the evolution of the universe.

"In my view, we live in very exciting times: the development of high luminosity polarized beams and polarized targets gives us access to a rich amount of high-quality data which will be used to gain a better understanding of quark confinement. This experimental progress, together with the advance of new theoretical tools, such as lattice QCD, promises interesting discoveries in the near future.

"It has been extremely fascinating for me to be part of the forefront research in nuclear physics and to be able to make contributions to this exciting field. Doing physics research has also affected me on a very personal level since through it I met my future husband."

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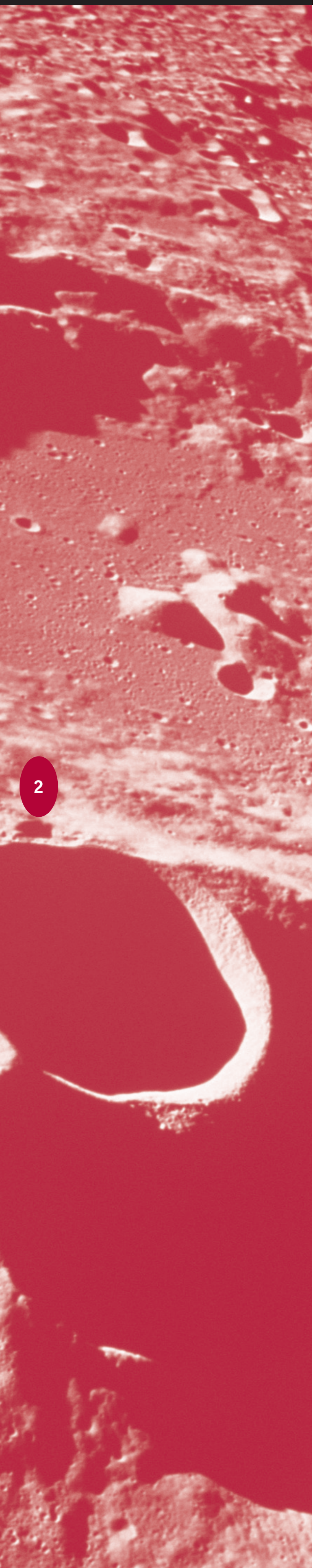

A Message from the Chair

Chaden Djalali

Welcome to another issue of *Quantum Leap,* the newsletter for friends and alumni of the Department of Physics and Astronomy. The department continues to make progress on all fronts thanks to dedicated staff, committed faculty, enthusiastic students, and engaged alumni and friends. Here are brief highlights of some of the activities of the past year.

As in the past few years, the main development continues to be the hiring of new faculty. During the past year, we have added two new members to our faculty. Yordanka Ilieva (experimental nuclear physics) joined us in January 2008. She received her doctoral degree in nuclear physics from the Bulgarian Academy of Sciences in 2001. Before joining our department, Yordanka held an assistant research professor position at George Washington University, where she worked on experiments probing light nuclei with real photon beams. Yuriy Pershin (computational physics and nanotechnology) joined us in August 2008. He received his Ph.D. in Physics in 2002 from the University of Konstanz, Germany, although the main part of his thesis research was done at the Grenoble High Magnetic Field Laboratory in France. After receiving his Ph.D., Yuriy held several research positions at the Center for Quantum Device Technology at Clarkson University, Michigan State University, and the University of California San Diego, where he mainly worked on quantum phenomena in nanoscale systems. I hope you will all join me in welcoming them.

Last year saw the departure of one faculty member and two staff members. After 29 years of service as a professor at the University of South Carolina, Gary Blanpied retired last May. He is now working as a research scientist with Decision Sciences Corporation of San Diego, Calif. One of our technical staff members, Richard Hoskins, left the department in September 2008 to work in Florida as lead chemist in a start-up company. Our graduate program coordinator, Laura Bouknight, left us to go to Boston. They were all valued members of our department; we will all sorely miss them and wish them well in their future endeavors. The department welcomes Jimmi Dee Brown, who has joined us as our new graduate program coordinator.

Our faculty, staff, and students continue to excel, as demonstrated by the awards they have obtained. A few of their many achievements deserve special mention. Professor Frank Avignone received the 2008 Citizens for Nuclear Technology Awareness Distinguished Scientist Award. Professor Sanjib Mishra is the University's 2008 Michael J. Mungo Distinguished Professor of the Year, and Professor Ralf Gothe received the 2008 Michael J. Mungo Graduate Teaching Award. Robert Sproul was one of the recipients of the College of Arts and Sciences 2008 Pamela W. Young Classified Staff Excellence Award. Our graduate student Mike Paolone won a first prize for his oral presentation at the 2008 University of South Carolina Graduate Student Day. Two of our undergraduate students won prestigious fellowships: Oliver Ralf Gothe was named the Barry M. Goldwater Scholar for 2008, and Matt Enright, who graduated in May with degrees in physics, mathematics, and French, will be a Fulbright Research Scholar in Germany. Congratulations to all of them!

The faculty continues to be very productive in scholarly activities. The number of publications, proposals, invited talks, and seminars are steadily increasing. In times of tight budgets, the faculty has been aggressively pursuing extramural funding, and the departmental overall funding has increased by 27 percent. Our department successfully organized and hosted two international conferences. Our community outreach efforts remain strong with regular visits to local elementary, middle, and high schools; training and enrichment programs for local schoolteachers; and the very popular Richard L. Childers Midway Physics Day at the South Carolina State Fair in October.

We truly would like to hear from our alumni and friends. Please send us news and information, and don't hesitate to drop by if you are visiting Columbia. I would like to thank all the faculty, staff, students, alumni, and friends who have generously contributed to the Department of Physics and Astronomy Funds. Your support directly benefits our students and the opportunities we can provide for them.

Best wishes to all, and let's stay in touch!

Quantum Theory Group

By Brett Altschul

Faculty members: Professors Brett Altschul, Vladimir Gudkov, and Pawel Mazur; Graduate students: Alejandro Ferrero and Andres Sanabria

In 2008, the department established the new Particle Theory Group, composed of Professor Pawel Mazur, Associate Professor Vladimir Gudkov, and newly hired Assistant Professor Brett Altschul. The group is involved in a variety of problems related to the most fundamental questions in physics: quantum gravitation and fundamental symmetries.

Professor Gudkov is one of the world's leading experts on fundamental neutron physics. Fundamental neutron physics can be considered simultaneously as a branch of nuclear physics and as a branch of particle physics (although it's not high-energy physics because it involves measurements made at extremely low energies). It is a branch of nuclear physics because neutrons can interact with nuclei via strong or weak interactions in a wide class of neutron-induced reactions, many of which are very sensitive both to the nuclear structure and to the symmetry properties of fundamental interactions. This is also a branch of particle physics because it enables one to study neutron properties: the particle's decay rate, features of specific decay modes, and intrinsic properties such as the neutron's electric dipole moment. Because of this dual nature, neutron physics has a great advantage for fundamental research, and neutrons have played a significant role in physics ever since their discovery.

With neutrons, one can test basic principles of theoretical physics, hadronic physics, the standard model of electroweak interactions, foundations of quantum mechanics, physics of many body systems (with many applications for nuclear structure, nuclear reactions, and nuclear astrophysics), and search for new physics beyond the standard model. The key feature of fundamental neutron physics is a high level of experimental accuracy. This is a crucial point because only high-precision low-energy experiments can be competitive with those carried out at high-energy accelerators. This feature, in turn, demands the high precision of theoretical calculations to be used for the description of processes in neutron physics, for designs of experiments, and for data analysis.

Therefore, the primary purpose of Gudkov's research is to improve theoretical understanding of low-energy neutron interactions with the emphasis on tests of the standard model and on possible searches for new physics. This includes the detailed theoretical analysis of neutron beta-decay and the precise description of properties of neutron interactions, including parity and time reversal violating processes in neutron-induced reactions. The accurate calculations of the processes are used as the basis to study possible manifestations of physics beyond the standard model (such as super symmetry, extra-dimensional gravity, etc.) and then to identify the observable that are most sensitive to new physics. Gudkov is working on a description of neutron-nuclear interactions using both the effective field theory approach and the microscopic theory of nuclear reactions, to develop the theory of parity—and time reversal—violating neutron interactions in a consistent way. This research involves a close collaboration with the fundamental neutron physics team at the Oak Ridge National Laboratory (ORNL) in order to provide timely theoretical support for undergoing and planning experiments at new Spallation Neutron Source (SNS).

The SNS will be the world's most powerful neutron source, and its construction was completed just last year. The SNS is well recognized as a very promising facility for many fields of research, including fundamental neutron physics. This is mostly because of its high neutron flux, which leads to the possibility of producing very large numbers of cold and ultra-cold neutrons and the possibility of measuring nuclear structures and neutron energies both with an accuracy that cannot be achieved in other experiments. With the prospect of new and more accurate measurements, it is appropriate and timely to review the current status of the theory associated with these experimental improvements with an eye toward the clarification of unresolved issues, as well as the identification of the breadth of physics that can be addressed at the SNS.

Gudkov's research contributes to the development of the ORNL program in fundamental physics and involves faculty members and students at the University of South Carolina in frontier physics programs at national laboratories.

Brett Altschul joined the department last fall, working on exotic physics beyond the standard model. A particular focus of his research has been looking for evidence of Lorentz symmetry violation. Lorentz symmetry is the symmetry of special relativity; the laws of physics are invariant under rotations of three-dimensional space and under "Lorentz boosts," which relate coordinate systems that are moving with respect to one another. Scientists have been performing tests of Lorentz symmetry since Einstein first proposed special relativity in 1905, but it has only been in the last decade or so that people have looked systematically at all the possible forms that a breakdown of Lorentz symmetry could take. Closely related to Lorentz symmetry is CPT symmetry. CPT symmetry says that all physics would remain unchanged if the universe were inverted in a mirror, all particles were changed into their antiparticles, and time were reversed. CPT ensures, for example, that matter and antimatter particles have the same masses. Since both Lorentz and CPT symmetry hold exactly in all known physics, any deviation from one or the other would be a sure sign of genuinely new physics. Many important advances in 20th-century physics came when it was discovered that certain symmetries were only approximate and did not hold exactly.

So it is interesting to ask how well we really know that Lorentz and CPT are exact symmetries. Many of the best constraints on violations of these symmetries come from astronomical observations. Astrophysical data

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can be used to place very precise constraints on a number of small effects; this works by taking advantage of two things that exist in outer space: very long distances over which particles may travel, and very high particle energies (the most energetic cosmic rays that strike the Earth's atmosphere are millions of times more energetic than the protons now circulating at the Large Hadron Collider).

For example, many of the most energetic gamma rays that reach us from outer space are believed to originate in the decay of neutral pions. Recent experimental advances—especially the construction of the High Energy Stereoscopic System telescope in the Namibian desert—have revolutionized ultra-high-energy gamma-ray astronomy. By measuring the photons emitted from active galaxies and other sources, it is possible to partially reconstruct the spectrum of the pions. This spectrum is interesting in its own right, but Altschul recently showed that it can be used to constrain deviations from Lorentz symmetry, which could manifest themselves as changes in the pion energy-momentum relation at very high energies.

Dr. Altschul has also been working on other exotic theories. In the last year, he showed how to place the tightest bounds ever on the charge of the photon. Although there is no known mechanism by which photons could carry a nonzero charge, it is still interesting to understand how well we know that the photon charge is actually zero. Altschul's method made use of the fact that charged particles moving through magnetic fields acquire Aharonov-Bohm (AB) phases. The AB phase is an intrinsically quantum mechanical effect that was first proposed by Professor Emeritus Yakir Aharonov. The AB phases for particles moving along different trajectories through a magnetic field are different. If photons carried a small charge, then radio waves that originated from a common source but arrived at slightly different locations on Earth would have different phases (because of their interactions with extragalactic magnetic fields). It turns out that the most sensitive measurements in radio astronomy are based on comparing the phases of radio signals measured at different observatories. This interferometric technique has been used to study active galactic nuclei billions of parsecs away—near the edge of the observable universe. If photons carried charges larger than 10^-46 times the charge of the electron, AB phases would mess up the images of the faraway galaxies. Altschul's new bound on the photon charge was an improvement of 11 orders of magnitude over the best previous constraint.

Along with Mazur's work on quantum gravity, these exciting research programs continue the department's tradition of focusing on some of the most basic questions in physics. Symmetry is one of the most important concepts in theoretical and experimental physics, and professors at South Carolina are actively involved in improving our understanding of it. This kind of work places the new Particle Theory Group right at the forefront of some of the most exciting areas of modern physics research.

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Outside of physics I like reading, gardening, and traveling to interesting places. Recently, I learned how to ride a bike and essentially discovered a new world of experiences. I am looking forward to the next challenge."

Yuriy Pershin

Yuriy Pershin

Yuriy Pershin received his Ph.D. in Physics in 2002 from the University of Konstanz, Germany, although the main part of his thesis research was done in the Grenoble High Magnetic Field Laboratory in France. His thesis was on electron and spin transport in systems with reduced dimensionality subjected to strong electric and magnetic fields. After receiving his Ph.D., Yuriy held several research positions at the Center for Quantum Device Technology at Clarkson University, Michigan State University, and the University of California San Diego, where he mainly worked on quantum phenomena in nanoscale systems.

Yuriy says, "Computational and theoretical nanoscience is a fascinating field of research. The laws of physics that govern the macroscopic world of our everyday life break down completely in the nano world because of the underlying quantum mechanical behavior of individual atoms, electrons, or photons. Therefore, going down to nanoscale is not only a technological miniaturization, but also a change of device operating principles. Nanoscience is an interdisciplinary field that has the potential to create many new materials and devices with wide-ranging applications, such as in medicine, electronics, and energy production.

"In particular, I am interested in understanding spin polarized transport in nanoscale structures. The role played by electron spin in solid-state physics is not yet well established, and there is a lot of interest to spin injection and relaxation processes as well as to spin polarized transport at the atomic level. Another direction of my research is electrical transport through biomolecules. I am excited to pursue my research at the University."

Condensed Matter and Nanoscale Physics Group

By Richard Webb

Faculty members: Professors Yaroslaw Bazaliy, Thomas Crawford, Richard Creswick, Scott Crittenden, Timir Datta, Milind Kunchur, Yuriy Pershin, and Richard Webb; postdoctoral fellow: Samir Garzon; graduate students: Baowei Liu, Gabriel Saracila (graduated), Jing Yang, Bochen Zhong, Yuquing Mao, Longfei Ye; undergraduate students: Matthew Rhoades, Giang Nguyen, Jim Talbert, and Rob Hedrick; biology master's student: Hari Patel

The current stage of development of electronics is characterized by extreme miniaturization, with some circuit elements reaching the size of 10s of nanometers. In this situation many physical effects that were previously unimportant start to play an adverse role, preventing further progress of electronic technology. In the last five to 10 years, devices that use the electron spin (as well as its charge) for information processing have been proposed, and recently new techniques for controlling the spin (or magnetization) using electric fields and currents (as opposed to magnetic fields) have been discovered. Electric control of spins has several advantages: it is easier to create electric fields than magnetic fields, especially in nano-size structures, and it removes many problems of integration with existing semiconductor technology. The term *spintronics* was coined for this type of technology.

We have ongoing research programs on spin injection from a magnetic material into nanoscale metals and semiconductor nanowires and have developed non local techniques to produce a spin current with zero charge current (Crawford, Bazaliy, Pershin, and Webb). Pure spin currents are a key ingredient in the realization of spin transistors that can have the potential advantage of storing more data in less space with less power consumption and using less costly materials. A second advantage of a spin transistor is that the spin of an electron is semipermanent and can be used as a means of creating a cost-effective, nonvolatile, solid-state storage device that does not require the constant application of current to sustain. It is one of the technologies being explored for Magnetic Random Access Memory (MRAM). In addition, passing current through a magnetic material can create a spin-polarized current that can be used to transfer spin angular momentum to another nanoscale magnetic material and reversibly switch the orientation of the magnet's moment. This spin-transfer effect may also result in the production of commercially viable MRAM and has been funded by Seagate Technology for the last two years. Switching magnetic materials at high frequencies with DC currents could potentially engender a whole new class of nanoscale spintronic devices, from self-generating GHz nano-oscillators to giant magnetoresistance sensors. In particular, we are studying the coherence of the spin transfer effect in the time domain to ascertain the time scales over which this physics can be employed for device applications.

One important focus of our area is the basic and applied research of potential superconducting, spintronic, optoelectronic, and nanoelectronic devices and/or materials for future applications in information processing, high-speed high-density electronics, and bio-, chemical, and radiation sensing. Thomas Crawford, Richard Webb, and the University's NanoCenter and engineering collaborators have recently received funding of more than $2 million for their programs on chemical, biological, and radiation sensor development using nanoscale devices. One goal of nanoelectronics is to process, transmit, and store information by taking advantage of the properties of matter present at the nanoscale that are distinctly different from macroscopic properties. We attempt to exploit any new physical phenomena related to the reduction in size of materials for these purposes.

The capability to engineer magnetism in traditionally nonmagnetic materials may launch an entirely new paradigm for magnetic data storage at the nanoscale. Gold nanoparticles become ferromagnetic when capped with thiols. The Crawford group is working to understand and extend this chemically induced magnetism into other nanostructured geometries as well as other chemical species with unique properties. In addition, they are adding DNA to the thiols and measuring the change in the electrical resistance of a gold film when the DNA/thiol is attached to the film.

To manufacture magnetic and electronic devices at 10 nm size scales, the metrology used for six sigma quality control in manufacturing must have verified spatial resolution in the 50 pm range. Measuring magnetic and electric fields at this size scale is both a technological and fundamental quantum physics challenge. When does quantum mechanics apply to nanoscale measurement? Recent observations of single electron spins suggest that, in principle, picoscale field mapping is possible. The Crawford group has NSF funding to explore new techniques for quantitative metrology with sub-nm resolution.

Scott Crittenden, who joined us last year to work on bioelectronics and scanning force microscopy (SFM), is still waiting for his laboratories to be renovated so that he can get started on his research program. He has already secured funding for his program from ARL/ARO and has set up a temporary laboratory in the NanoCenter, where he is currently training two graduate students (one in physics and one in biology) in developing novel nanoscale measurement and manipulation techniques, including the ability to measure the complete tip-sample interaction potential under a range of environments and a multi-probe SFM. He is also working with biologically produced

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protein nanowires. It has recently become clear that there are numerous genera of bacteria that produce free electrons as a normal by-product of metabolism. He is investigating the nanoscale mechanisms of electron transport in these electrogenic bacteria. Multiple researchers have shown experimental data suggesting that *pili* (hairlike filaments) produced by some of these genera are ohmic conductors. This is unusual for proteins, the building blocks of the *pili,* and suggests that nature may have constructed its own class of conductive polymers. Furthermore, Crittenden and many other groups across the world are now making fuel cells from electrogenic bacteria microbial fuel cells (MFCs) and powering them with waste biomass (e.g., grass, crab shells, wastewater streams, etc.). MFCs are a novel green alternative energy source that could eventually provide significant power from material that now has to be made to "go away." His work will provide opportunities for interesting interdisciplinary work between chemists, biologists, engineers, and physicists, which will most likely result in new energy sources that will aid in the transition to a biologically sustainable economy. In his second laboratory, to be completed in 2009, he will focus on obtaining a better understanding of the fundamentals of SFM and attempt to exploit the nonlinearity of the tip-sample interaction potentials to develop new techniques that will enable new experiments in nanosystems and provide advances in nanomanufacturing.

Last year Yaroslaw Bazaliy joined our department, after a one-year sabbatical. He is already a theoretical leader in the growing field of spintronics, a part of science that explores the ways in which electron spin can be used in electronic devices. This can only be done efficiently in very small, nanometer-sized samples. In addition, he has much experience in the fields of conventional and unconventional superconductivity, ferromagnet-superconductor proximity effects, and electron relaxation times in condensed matter systems and quantum critical behavior of transport parameters. He also plans to continue his work on the biophysics of cell crawling and actin-based motility. The proximity of his interests to those of the well-established experimentalists in our thrust area will allow for highly collaborative research projects. He is already collaborating with Crawford and Webb on spin dynamics in nanopillars.

Nuclear Theory Group

By Fred Myhrer

Faculty members: Professors Kuniharu Kubodera and Fred Myhrer

In April the Nuclear Theory Group succeeded in renewing the existing National Science Foundation grant for another three years with a significant increase in funding.

Our research associate, Dr. Anders Gårdestig, who joined us in December 2005, was offered a faculty position at Whitworth University in Spokane, Wash., and he moved there on July 1, 2008. We wish him all the best at his new place! We are continuing our collaboration with Anders on electroweak nuclear reactions, which play important roles in various astrophysical processes such as nuclear burning in stars, supernova explosions, and neutrino-nucleosynthesis.

During the last 12 months Kubodera and Myhrer presented papers on low-energy electroweak and strong nuclear reactions at international conferences in Germany, Norway, and the United States.

Kubodera served as the chair of the Organizing Committee for the Carolina International Symposium on Neutrino Physics, held at the University May 15–17, 2008. This conference was dedicated to our distinguished colleague, Professor Frank T. Avignone III. Together with Professor Wick Haxton (University of Washington, Seattle) and Professor Barry Holstein (University of Massachusetts, Amherst), Kubodera arranged the scientific program of the symposium, which had more than 30 invited speakers who are internationally renowned physicists from Europe, Asia, and North and South America.

Richard Webb is working on a variety of systems, including one-dimensional semiconductor nanostructures, quantum interference in GaAs heterostructures using a beam splitter employing two separate electron sources, magnetic tunnel junctions, and the development of NanoElectroMechanical Systems (NEMS). These nanostructures are attractive building blocks for nanoelectronics since their morphology, size, and electronic properties make them suitable for fabricating both nanoscale devices and interconnects. 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. Growth and characterization of semiconducting nanowires is also being performed in an attempt to understand nanoscale electronic properties. In addition, we can fabricate wires from almost any material as small as 25 nm using our electron beam lithography and frequently use this technique to fabricate electrical contacts to our nanowires. In our work on InN nanowires, we have been able to grow high-mobility wires that can be gated to provide transistor-like characteristics and have grown a very thin, high-quality insulating layer on the outside of the wire that can be used in our spin injection and sensor work.

Professor Timir Datta's research focus is in experimental gravitation and quantum properties of unconventional solids. Three graduate students, two professors from local historically black colleges, and one research collaborator work with him. They continue to develop a variety of techniques to detect and measure gravitational interactions and also independently determine the value of Newton's constant, G. These experiments require high-magnification angle measurements to achieve this goal. He is building an apparatus for multi-wavelength, diffractive goniometry. This novel instrument takes advantage of the high sensitivity associated with nonspecular scattering of the laser beams from the target or "negative reflection." Similar to negative refraction, this is a new concept. The idea of negative reflectivity was introduced by him and is being further developed by his group. He is also in collaboration with Dr. Michael Osofsky and Dr. Donald Gubser at the Naval Research Laboratory (NRL) in Washington, D.C. This collaboration is investigating energy loss in second-generation copper-oxide, HiTc conductors carrying alternating currents under high magnetic fields. With NRL he is also exploring the properties of group-15 based superconducting systems. In the topic of macroscopic quantum behavior, he studies the electronic properties of nanostructures with multiply connected Fermi-surfaces such as replica opals, which show unusual dispersion relations. Even before the discovery of graphene, in these opals he reported evidence of observing quantum effects in the extreme soft limit that is at temperatures as high as 60K and in only a few Tesla magnetic fields. He was the leader of the team of seven organizers and sorters for the superconductivity sessions of the March 2008 meeting of the American Physical Society; they planned the sessions for the nearly 500 invited and contributing speakers. During this meeting, which was held in New Orleans, he also chaired the session titled "Superconducting Nanostructures II."

Rick Creswick continues to investigate the arrow of time in the context of statistical physics and participated in a workshop at the Max Planck Institute in Dresden on the nature of time. It should be noted that in *Slaughter House Five,* Kurt Vonnegut, who survived the firebombing of Dresden in World War II as a Prisoner of War, introduced us to the Trafalmadorians, who "can look at all the different moments the way we look at a stretch of the Rocky Mountains, for instance. They can see how permanent all the moments are, and they can look at any moment that interests them. It is just an illusion we have here on Earth that one moment follows another one, like beads on a string, and that once a moment is gone it is gone forever." Creswick also continues his work with Frank Avignone on the development of low-temperature bolometers used in searching for dark matter and zero neutrino double beta decay.

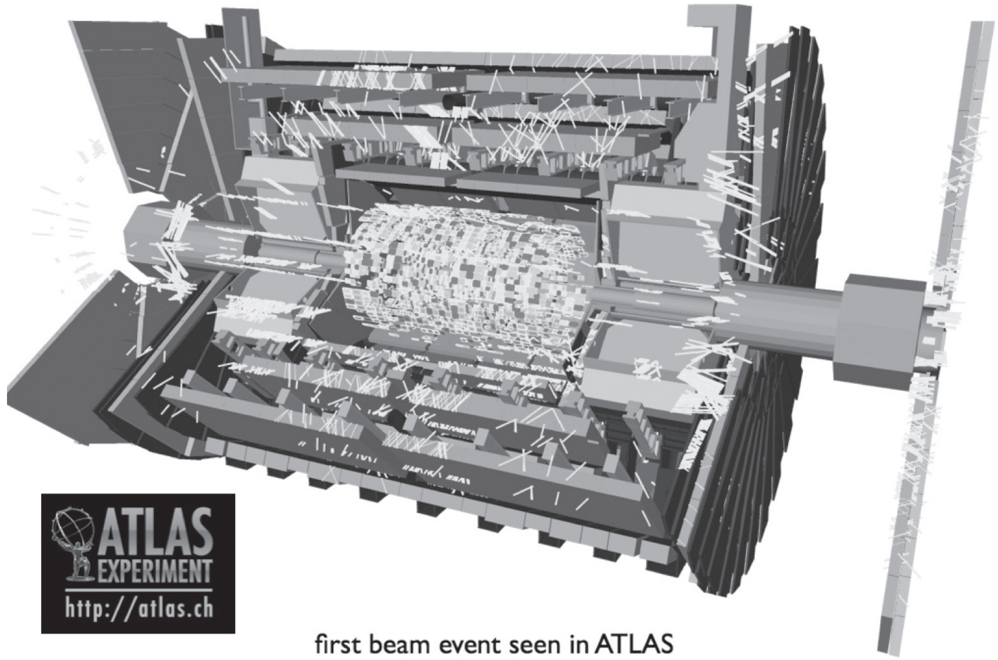
Milind Kunchur is another member of the CM/Nanoscience Group who works in the areas of transport in superconductors and nanostructured materials and in human hearing. His sabbatical-leave article, which is featured in this issue, provides more information about his research activities.

High Energy Physics Group

By Roberto Petti

Faculty members: Professors Frank T. Avignone III, Sanjib Mishra, Roberto Petti, Milind Purohit, Carl Rosenfeld, and Jeff Wilson; heavy quark postdoctoral students: Woochun Park; neutrino postdoctoral students: Azizur Rahaman; heavy quark graduate students: Xurong Chen, Hongxuan Liu, Arjun Trivedi, and Ryan White; neutrino graduate students: Jae Jun Kim, Chris Kullenberg, and Jiajie Ling

The ATLAS Experiment at the Centre for European Nuclear Research (CERN) in Geneva, Switzerland



first beam event seen in ATLAS

The start-up of the Large Hadron Collider (LHC) at CERN has been the main scientific event in high-energy physics this year. The first beam was successfully circulated in the new accelerator on Sept. 10, 2008, and the event received unprecedented global media coverage. The LHC program can be considered the most ambitious and challenging scientific experiment ever performed for its complexity, based on the number of scientists involved and more than two decades of preparation. The operation of the LHC will hopefully open a new era of scientific discoveries. The LHC ring, 27 km. long, accelerates and collides two proton beams with a center-of-mass energy of 14 TeV. The ATLAS experiment at the LHC will clarify the mechanism, which is at the origin of the masses of all known particles. It will also try to probe the mysterious dark matter of the universe—visible matter seems to account for just 5 percent of what must exist, while about a quarter is believed to be dark matter. The energy reached is about 10 times higher than previous experiments, and it will allow us to probe matter, as it existed at the very beginning of time.

Our group is now actively contributing to the exciting physics program of the ATLAS experiment at the LHC. Professor Milind Purohit, postdoctoral fellow Woochun Park, and Assistant Professor Roberto Petti have all spent significant amounts of time at CERN during the last year. Professor Jeff Wilson and graduate student Arjun Trivedi are contributing as well.

The South Carolina group participated in several aspects of commissioning, calibration, and reconstruction of the forward muon system in ATLAS. Purohit is contributing to muon performance studies and Park to muon software. We are all involved in a future upgrade to ATLAS muon detectors when the LHC becomes the super-LHC (as the LHC goes to higher luminosities). To this end, one of the interesting candidate detectors is a new kind of Micro-Pattern Gas Detector called Micro-Mesh Gaseous Structure (MICROMEGAS). Park and Petti participated in test-beam exposures of MICROMEGAS prototypes and to the corresponding data analysis. Purohit and Park started to get involved in the data analysis to search for new super-symmetric particles. We all will contribute to the physics data taking, which is expected later in the fall.

Graduate student Arjun Trivedi began as a full-time research assistant this summer. A major part of his time so far has been spent in familiarizing himself with the ATLAS software framework and setting up rudimentary programs to collect and organize data for physics analysis. He has had the opportunity to visit Brookhaven National Lab (BNL), New York, and the Centre for European Nuclear Research (CERN), Geneva, Switzerland. At BNL earlier in the summer he had the opportunity to interact firsthand with people who were experienced with ATLAS software and it was a tremendous opportunity for him to get started in his learning process. Currently he is at CERN, where he has taken part in a test beam run for MICROMEGAS detectors.

Proposal for a New High-Resolution Neutrino Experiment at Fermilab

The Fermi National Accelerator Laboratory (Fermilab) in Batavia, Ill., plans to build a new 8 GeV proton driver to upgrade the main injector beam line. The project (Project X) 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 neutrino 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, HiResMn, to exploit the unprecedented neutrino fluxes foreseen with Project X at Fermilab. A letter of intent with the description of the detector and of its physics potential was submitted in the spring. 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 $Dm^2=m_1^2-m_2^2$. At present we have only upper limits on the mixing angle q_{13} and know nothing about the sign of Dm^2 (neutrino mass hierarchy). Furthermore, we don't know to what extent anti-neutrinos behave differently from neutrinos (violation of charge-parity [CP] symmetry). 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, HiResMn, will reduce systematic uncertainties related to neutrino fluxes and neutrino interactions, thus increasing the sensitivity of LBL experiments to oscillation parameters.

Overall, HiResMn 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).

CP Violation Experiment BaBar at Stanford's Linear Accelerator Lab

The standard model of particle physics describes three of four fundamental forces of nature but is unable to unify gravity. Nor does the theory account for the asymmetry of matter and antimatter in the universe. This suggests that our understanding of the origins of the universe is incomplete and that new physics beyond the standard model exists.

The BaBar experiment, located at the Stanford Linear Accelerator Center (SLAC), was designed to measure CP violation in the B meson system. All measurements of CP violating parameters in the B-quark sector confirm the predictions of standard model, and the CP violation predicted by the theory is not large enough to explain the asymmetry in the universe. However, the BaBar experiment also provides sensitivity to search for new physics, namely in decays of particles that contain the lighter charm quark. Graduate student Ryan White is studying the decays of charged D mesons. This is a search for CP violation where it is not expected to be in the standard model. If we discover CP violation in decays of charm mesons, we have a clear indication of new physics beyond the standard model.

The Study of Neutrino Oscillations and Neutrino Physics

Mishra, Rosenfeld, and postdoctoral fellow Rahaman 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 HiResMn experiment. Several publications of NOMAD analyses are in preparation. Graduate student Karen Wu defended her Ph.D. thesis on the measurement of neutrino-nucleon cross-sections in NOMAD under the guidance of Mishra.

Astronomy Group

By Varsha Kulkarni

Faculty members: Varsha Kulkarni; graduate students: Soheila Gharanfoli, Yeuncheol Jeong, Joe Meiring (graduated in August 2008), Debopam Som, Lorrie Straka, and Legna Torres

Professor Varsha Kulkarni continued research in extragalactic astronomy and cosmology, along with graduate students and other collaborators. Our research uses primarily optical, infrared, and ultraviolet facilities and is funded by the NSF and NASA. New observations were obtained with the Very Large Telescope (VLT), the Magellan Clay Telescope, and the Gemini-South telescope in Chile, Gemini-North and Keck telescopes in Hawaii, the Apache Point Observatory (APO) in New Mexico, and the Spitzer Space Telescope. Our goals are to measure element abundances, 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. With VLT, Keck, and Gemini, we have carried out emission-line integral field imaging and adaptive optics imaging of the absorbers. With Magellan, we have discovered several new quasar absorber galaxies at intermediate redshifts with near-solar or supersolar metallicity, which may help in part to solve the "missing metals puzzle." We have also started a newly funded NASA Spitzer program for IR spectroscopy of quasars. Our research resulted in four refereed and two unrefereed publications within the past academic year. Several more papers are in preparation.

Graduate student Joseph Meiring completed his Ph.D. dissertation on element abundances in sub-DLA absorbers and is now a postdoctoral fellow at the University of Louisville. Graduate student Soheila Gharanfoli defended her Ph.D. dissertation on high-resolution imaging and spectroscopic confirmation of quasar absorber galaxies in fall 2008. Graduate student Lorrie Straka is working on emission-line imaging of galaxies in quasar fields. Graduate students Debopam Som and Legna Torres joined our group in fall 2007 and are working on spectroscopy of gravitationally lensed quasars and element abundances in dusty absorbers. Graduate student Yeoncheol Jeong and undergraduate student Julianne Goddard joined our group in fall 2008. Graduate students Meiring and Gharanfoli presented at the American Astronomical Society conference in Austin, Texas, in January 2008. Graduate students Som, Straka, and Torres discussed their work at the first student conference organized by the department in August 2008. Professor Kulkarni discussed the "The Cosmic Odyssey of the Elements" conference in Aegina, Greece, in June 2008 and "The Sloan Digital Sky Survey: From Asteroids to Cosmology" conference in Chicago in August 2008, as well as some colloquia/seminars at other institutions.

In other news, Dr. Daniel Overcash and Kulkarni held a public lunar eclipse-viewing event in February 2008 at the University's Melton Observatory, with help from other observatory staff. This event drew a big crowd and was great fun for everyone!

Advanced Solutions Group (ASG)

By Joseph Johnson

Dr. Joseph E. Johnson, professor of physics, leads a group (ASG) for the development of information systems (www.asg.sc.edu) as well as a group (Nexus) for the study of complex problems (www.nexus.sc.edu). Nexus has just completed a $2.5 million grant with DARPA to investigate potential metrics for describing networks with particular emphasis in metrics that are sensitive to aberrations such as attacks on the Internet. This work, along with patents and technical papers, can be found at www.ExaSphere.com. It was proved that every possible network topology is isomorphic to the infinitesimal generators of Markov transformations. The resulting metrics utilize (Shannon and Renyi') entropy on the rows and columns, thus having sensitivity to changes in network transmissions into and out of the various nodes. These entropies are expressed as a spectrum, which is characteristic of the specific network topology, and the resulting software (in JAVA and Mathematica) is applicable to any type of network such as electrical grids, transportation networks, and financial, or social, networks. Two associated patents are pending.

Nexus is also doing research on a new database system, as well as a new form of game theory that addresses some of the difficulties with standard von Neumann game theory for n-person games and alliances. Patents are pending on both of these. One patent has just been awarded for a new mathematical foundation for computations with logical and numerical uncertainty, which generalizes Boolean logic and the real number system along with methodologies for dealing with the associated information content (entropy measures). Applications of this work are being studied for measurements in quantum theory. ASG also continues grants and contracts in law enforcement and emergency management. The total grant funding of ASG has been more than $12 million since 1992.

Experimental Nuclear Physics Group

By Steffen Strauch

Faculty members: Professors Chaden Djalali, Ralf Gothe, Yordanka Ilieva, Steffen Strauch, and David Tedeschi; postdoctoral students: Simona Malace, Kijun Park, Mike Wood (leaving), Mike Paolone (incoming); graduate students: Nathan Baltzell, Lewis Graham, Haiyun Lu, Mike Paolone, Evan Phelps, Zhiwen Zhao, Eric Graham, Shakil Mohammed, Robert Steinman, Ye Tian, and Tayfun Akyurek

Our experimental intermediate-energy nuclear physics group (Chaden Djalali, Ralf Gothe, Steffen Strauch, and David Tedeschi) increased to five faculty members when Yordanka Ilieva joined the group. Other members of the group include three postdoctoral research associates, 11 graduate students, and several undergraduate students. Our experiments with multi-GeV photon and electron beams is based at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) where we conduct basic research of the atom's nucleus and its constituents on the quark level. All members of the group are extremely active and play leading roles within our collaborations in the pursuit of this research. We are spokespeople of eight approved experiments at Jefferson Lab. The members of our group have given 19 invited talks and seminars in 2008 alone, which is a token of the international recognition our group is receiving. We have published dozens of articles on our collaborative research. Particularly, our group focuses on three main areas: the search for hadron medium modifications, the study of baryon resonances, and few-body physics. We give here a short update on our recent activities.

Understanding the structure of hadrons in terms of its constituents (quarks, antiquarks, and gluons) is of fundamental importance in nuclear and particle physics; ultimately such an understanding is necessary to describe the strong force. Whether or not this structure is significantly different for hadrons in the nuclear medium is still an open question. Our group is engaged in both the study of meson and nucleon medium modifications. In our current experiment in Hall B at Jefferson Lab, we have measured electron-positron pairs from the decay of the vector mesons, which were photoproduced off deuterium and nuclei as dens as iron or titanium (g7). These data provide the most direct and clean experimental test of the assumption of medium modification of vector-meson properties, like the mass or the width of these particles. We have finalized the analysis of our data and published the results. Of particular interest are possible in-medium effects on the properties of the ρ meson. We observe no significant mass shift and some broadening consistent with expected collisional broadening for the ρ meson. These results contribute to our understanding the impact of nuclear matter on particle properties. In an attempt to study possible in-medium modifications of bound nucleons, we have measured the proton recoil polarization in quasi-elastic electron scattering from ^{4}He at Jefferson Lab in fall 2006 (experiment E03–104). The polarization-transfer observables from this experiment revealed strong medium effects. It provides us with precise data that will allow a more detailed study of the knockout reaction on the bound proton. Graduate student Mike Paolone worked on this experiment and successfully defended his Ph.D. thesis in August 2008. The analysis of the induced polarization is underway.

Our group has two approved experiments as part of the frozen-spin-target program in Hall B (FROST). In this experiment we study a number of polarization observables in single and double *pion* photoproduction, using various combinations of polarized beam and polarization orientations of the proton target with the goal to extract and interpret the quark-gluon substructure of nucleon resonances. The first part of the FROST experiments ran from October 2007 to January 2008. The group supported the run with one of our postdoctoral students as the on-site manager (run coordinator) during part of the experiment. A second beam time is scheduled in 2010. FROST is one of the major projects of the CLAS Collaboration and will provide research opportunities for student projects on all levels for many years to come. The newly established Excited Baryon Analysis Center (EBAC) at Jefferson Lab will be instrumental in providing theoretical input to the data analyses of our collaboration.

The first (e1-6) results of transition form factors up to four momentum transfers of $Q^2 = 4$ GeV^2 for several baryon resonances have been published, and we are now focusing on the analysis of scaling and high-t phenomena, Transition Distribution Amplitudes (TDA), and the resonance search at higher invariant masses.

The group is looking positively to the future as Jefferson Lab's 12 GeV upgrade project cleared a critical hurdle this summer. The lab successfully passed a review that was required before the lab can request DOE approval to start construction. Construction is expected to begin in fiscal year 2009. With the development and design of a new addition to the time-of-flight spectrometer for the CLAS detector in Hall B, our group has a major part in the upgrade project. Testing and prototyping of detector elements are performed in the Neutron Generator Building at South Carolina. The project is a unique opportunity for undergraduate education and to involve young students in nuclear-physics research early in their careers. The 12 GeV upgrade at Jefferson Lab will allow us to push the transition form factor measurements up to $Q^2 = 12$ GeV^2 and thus to investigate the transition from constituent quark to partonic degrees of freedom with unprecedented accuracy.

Gary Blanpied Retires

After 29 years of service as a professor at the University of South Carolina, Gary Blanpied retired last May. He now works as a research scientist at Decision Sciences Corporation of San Diego, Calif. The project they are currently working on is the Guardian Muon Tomography (GMT), which uses 4,032 12– and 16–foot drift tubes to measure the passage of cosmic ray muons and electrons through cargo containers at ports, vehicles at border crossings, and commuter trains in large cities. This Homeland Security project is an application of the technology which has been developed for nuclear and high-energy physics experiments.

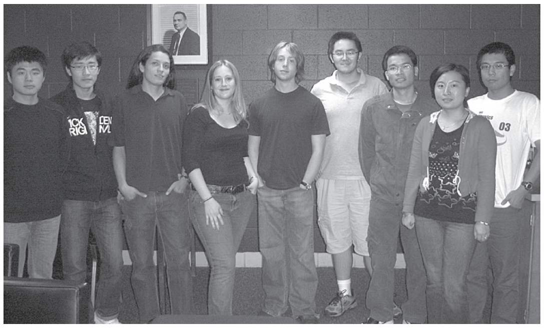
Gary started as a tenure-track assistant professor in 1979. He worked at many particle accelerator facilities, including those at Los Alamos, N.M.; Saclay, Orsay, and Grenoble, France; Villigen, Switzerland; Brookhaven, N.Y., and Jefferson Laboratory in Virginia. He worked on the Accelerator Production of Tritium Project before joining (2002) a collaboration of LANL physicists charged with determining the applications of naturally occurring cosmic ray particles.

In the next few months he and his wife, Deborah, will be staying in South Carolina. Gary travels up to every two weeks to Los Alamos to work on the prototype detector. They will be moving to San Diego within a year.

Updates from the Director of Graduate Studies

By David Tedeschi

Greetings!



These graduate students are among those who joined the department last fall.

This fall semester got off to a great start. Our graduate program remains strong and presently totals 53 with the addition of 12 new students this academic year. In addition to our new graduate students, we've also welcomed a new staff member. Dee Brown is the new graduate program coordinator for our graduate program. With the help of our new coordinator, we've been able to make our new graduate students' transition a bit easier.

This year we've implemented the new Graduate Student Mentor Program. The program pairs our new graduate students with upper-level students who are there to help with any questions or challenges that a new student might face. In addition to the mentor program, we also developed a calendar of events to highlight important activities and events such as the New Student Orientation, the Student Conference, and various scheduled workshops and trainings. Our graduate students were also invited to a fun day of bowling with the faculty. All of these exciting additions ensured that our new incoming graduate students received a warm reception once they arrived.

The enhancements that I have mentioned above are only a few among the many efforts to improve our graduate program. The physics and astronomy department is always working to improve the quality of the program and better fulfill the needs of our students.

Staff News

Comings and goings over the past year …

Laura Bouknight, graduate program coordinator, decided to move to the Boston area and get married. She is now, happily, Laura Smith. She and her husband, Mike, were married on Sept. 27. Laura is currently working at Bridgewater State College with the Institute for Regional Development. We miss her but wish her all the best.

We were very happy to have Dee Brown join our team last March as the new graduate program coordinator. We must really like the College of Journalism and Mass Communications because, like Laura, Dee also received a BA in advertising. Perhaps it's a conspiracy to get our department's name out there more. Hmmm….

At the end of August, Richard Hoskins decided that living with his family in Florida was better than working in the Department of Physics and Astronomy. Can you imagine? Actually, a great opportunity presented itself for him to become the lead chemist of a start-up company. Richard is terribly missed, but we are so happy that he's back with his family.

Robert Sproul, Bob Simmons, Ray Edmonds, Mary Papp, and Beth Powell are as busy as ever. One of their most recent tasks was working around renovations in the main office during the summer. It would be an understatement to say it looked like a tornado went through the office. It's amazing how messy removing and building walls can be. Bob now has an office with an actual air unit, which came in very handy during those last hot days of the summer, and Beth has her own office. The walls are still pretty bare, and there are still boxes to be organized, but it's getting there. If only spare time existed.

Particle Astrophysics Group

By Frank T. Avignone

Faculty members: Frank T. Avignone, Richard Creswick, Horacio Farach, and Carl Rosenfeld; postdoctoral research associate: Iulian Bandac; graduate students: Todd Hossbach, Carlos Martinez, Leila Mizouni, and Seth Newman

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 group was early in the field when it made the first terrestrial CDM search. CDM is needed to explain the dynamics of galaxies and certain 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 Carolina group, inspired by the astrophysics group at Max Planck Institute in Munich, led the first terrestrial search for the CDM in the Homestake goldmine, 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 University of 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 by an international collaboration led by Richard Creswick. It uses the coherent Bragg conversion of axions to photons in single crystals when the line from the detector to the solar core satisfies a Bragg condition. Later, other groups used it worldwide.

The University group now concentrates on two searches for the exotic zero-neutrino nuclear double-beta decay only possible if neutrinos have mass and are their own antiparticles (Majorana particles). It 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 flavors.

The South Carolina group has been involved in the CUORICINO double-beta decay experiment in the Gran Sasso laboratory in Assergi, Italy, from the beginning. It has now set a lower limit on the half-life for the zero-neutrino double-beta decay of ^{130}Te of $3\text{x}10^{24}y$ 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 University group also played a key role in establishing the Majorana ^{76}Ge double-beta decay project, which will eventually be 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.

Updates from the Director of Undergraduate Studies

By Jeffrey Wilson

Professor Gary Blanpied retired from the physics department last spring and left the undergraduate program in good shape. This semester we have more than 50 students pursuing physics degrees of some form. We had five graduates last spring and summer semesters.

A new advanced laboratory-based optics course is being taught this fall by Professor Thomas Crawford and has five students enrolled. One of the featured pieces of equipment is a titanium-sapphire laser capable of producing pulses of 17-femtosec duration. This laser is a research-grade tool. In addition, we also have a magneto-optical trap capable of collecting and cooling atoms to levels appropriate for demonstrating Bose-Einstein condensation. We expect this state-of-the-art course to become one of our more popular capstone offerings in years to come.

Faculty involved with the introductory engineering physics have begun regular meetings with faculty from the College of Engineering and Computing in an effort to better match those courses to the needs of the students taking them. We intend to extend this process to the point of measuring how well students are learning individual concepts. We are beginning to apply this process across the board in our physics major courses as well in order to produce a better experience for all of our undergraduates.

Conferences

Carolina International Symposium on Neutrino Physics (CISNP)

The physics department of the University of South Carolina held an international symposium from May 15 to 17, 2008, to celebrate the 75th birthdays of Frank Avignone and Ettore Fiorini and to commemorate the 75th birthday of the late Peter Rosen.

This meeting, titled the Carolina International Symposium on Neutrino Physics (CISNP), covered the following topics, among others: neutrino physics (oscillations, double beta-decay, supernova explosion, neutrino nucleosynthesis, etc.), axions, dark matter, dark energy, and cosmology.

In addition to invited talks, the workshops included the oral presentations of selected contributed papers, and prospective participants were encouraged to submit contributed papers. The proceedings were published.

The CISNP Scientific Advisory Committee included Wick Haxton (Seattle), Barry Holstein (Amherst), and Kuniharu Kubodera (University of South Carolina).

The CISNP Organizing Committee included the following members of our department: Richard Creswick, Chaden Djalali, Vladimir Gudkov, Milind Purohit, and Kuniharu Kubodera, chair.

Beach Series 2008

The Eighth International Conference on Hyperons, Charm, and Beauty Hadrons was held at the University of South Carolina Columbia June 22–28, 2008. This conference continues the BEACH series, which began with a meeting in Strasbourg in 1995. The series now offers a biennial opportunity for both theorists and experimentalists from the high-energy physics community to discuss all aspects of hyperon and heavy-flavor physics. The conferences in 2004 and 2006 attracted more than 100 participants.

The following topics exemplified the broad scope of the conference: CP violation in K and B-meson decays, heavy quark physics, heavy quarkonium production and decay, light meson production and neutrino flux, heavy quark effective theory, lattice QCD and nonrelativistic QCD, precise electroweak measurements, hyperon physics, hadronic-neutrino physics, top-quark physics, and new experimental facilities and projects.

The conference was intended to be a productive experience for graduate students and senior researchers alike. The organizers fostered an informal ambience conducive both to collaboration and to networking.

Alumni News

Previous Graduates—Where Are They Now?

Richard Foster will be working as an actuarial associate at Towers Perrin in Seattle, Wash.

Joseph Meiring is doing postdoctoral work at the University of Louisville in Kentucky.

Vladimir Montelegre is searching for a position.

Mike Paolone is doing postdoctoral work at Jefferson Laboratory in Newport News, Va.

Gabrielle Saracilla is an electromagnetic engineer at General Electric Healthcare Diagnostic Imaging in Florence, S.C.

Isai Sundararaman is searching for a position.

Awards

Graduate Students

Joseph Meiring is the recipient of the 2008 Graduate Student Research Award.

Michael Paolone placed first in the 2008 Graduate Student Oral Presentation with “A Search for Modified Proton Structure in Dense Helium Nuclei.”

Abraham Pernicka is the recipient of the 2008 Graduate Student Teaching Award.

Undergraduate Students

The department had a number of high-performing undergraduate physics students in 2008, and several of our annual awards had multiple winners.

Matt Enright graduated in May with degrees in physics, mathematics, and French and will be a Fulbright Research Scholar in Germany. Matt plans to earn a Ph.D. to prepare him for a career in university teaching and research in nuclear physics.

Oliver Ralf Gothe was named the Barry M. Goldwater Scholar for 2008.

Benjamin F. Garrett, **Joshua S. Hendrickson,** and **Kevin J. Ludwick** are the recipients of the Nina and Frank Avignone Fellowship.

Erica L. Raheja received the College of Arts and Sciences Rising Senior in Physics Scholarship Award.

William D. Swan and **Kevin P. Wilson** are the recipients of the Rudy Jones Physics Award.

Staff

Robert Sproul is a recipient of the 2008 Pamela W. Young Classified Staff Excellence Award.

Faculty

Ralf Gothe received the 2008 Michael J. Mungo Graduate Teaching Award.

Sanjib Mishra was awarded the 2008 Michael J. Mungo Distinguished Professor of the Year Award, the University’s most prestigious award.

Dr. Andrew A. Sorensen presents the 2008 Michael J. Mungo Distinguished Professor of the Year Award to Sanjib Mishra.

Frank T. Avignone III is the 2008 recipient of the Fred C. Davison Distinguished Scientist Award. The award is presented by Citizens for Nuclear Technology Awareness (CNTA).

Sanjib Mishra

Mungo Distinguished Professor of the Year

Physicist Sanjib Mishra doesn't have a philosophy of teaching. But you might say this year's Michael J. Mungo Distinguished Professor of the Year winner operates his classroom according to a slightly modified rule of his discipline: for every action, there is a reaction.

Mishra, a particle physicist, received two master's degrees and his Ph.D. from Columbia University. He was an assistant professor at Harvard University from 1991 to 1999 before coming to Carolina in 2000. Carolina students, he said, are "inspirational."

Mishra works with a core group of undergraduates who are research assistants in his lab. One student went on to become an Arabic scholar and now is working on a Ph.D. in chemical engineering. Others have won Goldwater and National Science Foundation scholarships.

"They are a pleasure to work with," he said. "They are working in my lab, helping me get answers to my questions. That's a pleasure. The University has done such a remarkable job in terms of encouraging undergraduate research. It is such a positive program."

R.L. Childers Midway Physics Day at the South Carolina State Fair

The department extends our thanks to the South Carolina State Fair again this year for the hard work and support of the 2008 R.L. Childers Midway Physics Day at the South Carolina State Fair. Midway Physics Day was held on Tuesday, Oct. 14, 2008, and we had a wonderful turnout with approximately 2,500 high school students in attendance from across the Palmetto State.

Back by popular demand, our faculty, staff, graduate, and undergraduate students presented physics demonstrations on stage in the meeting tent. A number of hands-on physics activities were held throughout the day. Some of our faculty members and students were stationed at various rides to help with calculations needed to complete activity sheets provided by their school or by the Midway Physics Day Web Site.

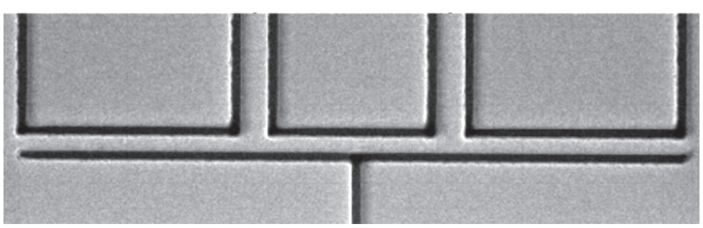
Midway Physics Day continues to grow in popularity, and we appreciate all of the work that everyone puts into making it happen.

How I Spent My Sabbatical

By Milind N. Kunchur

My sabbatical during spring 2008 proved to be a fruitful period of research rejuvenation and growth. Condensed matter physics has been evolving and crossing into other disciplines, such as nanotechnology and the biological sciences, and it is at these crossroads where some of the most exciting future discoveries and inventions lie. One of my objectives during the sabbatical period was to form ties and establish collaborations with other institutions in the areas of nanostructured superconductors, psychoacoustics, and auditory neurophysiology.

My group is exploring several fundamental phenomena in nano- and micro-patterned superconductors, such as the time evolution of quantum phase slip processes and the dynamics of non-equilibrium vortices. From an applications perspective, interconnects made of superconducting materials hold the promise of playing an important role in the microchips of the future. As integrated circuits become more compact—packing more and more devices onto ever-smaller areas—a bottleneck that stands in the way of further scale reduction is internal heat generation. The use of superconducting interconnects avoids one component of this heat generation. Collaborators at Argonne National Lab (principally Dr. Wai Kwok, group leader of the Superconductivity and Magnetism Group) are fabricating the superconducting nanowires for this work by and at Northern Illinois University (principally Professor Zhili Xiao, who is an expert on materials fabrication). The figure below shows a 150nm-wide nanobridge fabricated in a 100nm-thick niobium superconductive film using focused Ion Beam Lithography preceded by Electron Beam Lithography (EBL).



Superconductive niobium nanobridge

The electromagnetic measurements on these nanowires is carried out in my group's facilities at the University of South Carolina, where we possess instrumentation that is one of the foremost in the world in terms of its ability to explore dissipative phenomena in superconductors. The results of this research in superconductivity were presented at this year's annual American Physical Society (APS) March meeting in New Orleans. This work is funded by the U.S. Department of Energy (Basic Energy Sciences program).

The other research area that was developed during my sabbatical is psychoacoustics and neurophysiology of human hearing. Like nanotechnology, the science and technology of sound and hearing represents a field that crosses many disciplines: the production and transmission of sound waves represent physical phenomena; the electronic instrumentation needed to produce and process the electrical signals involves electrical and audio engineering; the reception of the sound by the ear and its transduction involves the biology of the ear and brings in elements from the medical fields of otology and audiology; the processing of auditory nerve signals in the brain involves the neurophysiology; and finally the behavioral response of the subjects involves psychology.

My previous behavioral studies on human subjects showed that we are able to discern timing alterations on a five-microsecond time scale. This result was unexpected for the hearing community and was greeted by a sense of shock and disbelief. One of the objections raised was that it should be theoretically impossible for a human to be able to hear such small time differences, based on previously understood auditory neurophysiology. Another comment raised was that numerous previously published psycho-acoustical experiments had failed to demonstrate such acute temporal sensitivity, making it seem that my result was at odds with all of the previous work; indeed the associate editor at the *Journal of the Acoustical Society of America* (JASA) stated that my result brought into question 100 years of research in this field.

Since I lacked a formal background in psychology and neurophysiology, I visited key researchers at the University of Wisconsin at Madison to gain a deeper understanding of these other aspects of hearing research. My host, Professor Donata Oertel (a former president of the Association for Research in Otolaryngology and one of the foremost auditory neurophysiologists in the world) in the Department of Physiology, and Professor Bob Lutfi (chair of the Department of Communication Disorders and an associate editor of JASA) were two of the principal people whose labs I visited. In addition, I also met with other professors from the Departments of Psychology, Physiology, and Neuroscience and other hearing-related fields. Professor Lutfi's lab offered me the opportunity to learn more about traditional protocols and data analysis used in behavioral studies. Professor Oertel's lab gave me insight into the neural processes that take place at a cellular level that might sharpen the resolution of time in mammalian hearing. One such neuron that plays a role in temporal convergence is the octopus cell, which acts as a kind of synchronous AND gate. The

How I Spent My Sabbatical continued from pg. 17

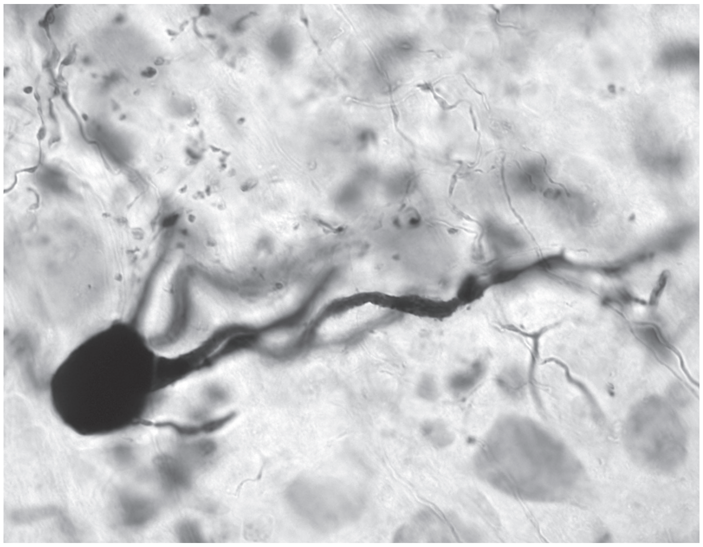

A micrograph of an octopus neuron that may play a role in encoding temporal aspects of sound

figure to the left shows a picture of an octopus cell taken in Professor Oertel's laboratory during my visit.

Besides the basic-science aspects of this hearing research, there are practical implications for the technologies of sound reproduction, transmission, and storage. This research was the first to concretely prove that present consumer-audio digital standards are insufficient to maintain complete fidelity (previously such claims were based on anecdotal evidence only). This research has elucidated some origins of temporal distortions in audio reproduction and their possible solutions.

The results of this work were presented at the annual midwinter meeting of the Association of Research in Otolaryngology (ARO) in Phoenix, Ariz., and the meeting of the Acoustical Society of America (ASA) in New Orleans and were presented to the Bose Corporation when company officials visited the University. This research on human hearing was partially funded by the University of South Carolina Office of Research and Health Sciences Research Program.

2008 Department of Physics and Astronomy Christmas Party

The Department of Physics and Astronomy once again had a wonderful turnout for our Christmas party this year and missed those who were unable to attend. It was nice to congregate with everyone outside of our work atmosphere and have some delicious food at the same time! We thank everyone who helped prepare the amazing "dishes."

Here are a few pictures from our evening. The children especially seem to have a wonderful time every year!

Professor Jeeva Sachith Anandan: A Life in Service of Theoretical Physics

By Pawel Mazur

I am writing these words about Jeeva some five years after his tragic passing as a tribute to a great man and friend. Jeeva would have been 60 on June 10 of this year. At a risk of sounding banal or trivial, I wish to say that Professor Jeevanandam Sachith (June 10, 1948–July 29, 2003) was a decent man and a great scholar who devoted his life to service in theoretical physics.

The present writer first came across Jeeva's name at the time he was still an undergraduate student of theoretical physics when Dr. Anandan's famous paper on the so-called Sagnac Effect in General Relativity had appeared as a Pittsburgh preprint and an article (J. Anandan, "Gravitational and Rotational Effects in Quantum Interference," *Physical Review Letters*, D 15, 1448–1457 [1977]).

Later on our paths crossed when in 1983 Anandan received the prestigious Gravity Research Foundation First Prize in Boston, Mass., and the present speaker the third prize, and again when our world-lines first came into coincidence in June 1985 at the Fourth Marcel Grossmann Meeting in the Eternal City, Roma (Rome).

If it were not for him, I would have never considered leaving UCLA for a position at the University of South Carolina. This was in 1988; I had plenty of time, I thought at that time. Jeeva had been encouraging me to think about the sense of the basic security a tenured position gives to somebody who is possessed by the internal need to know how nature works.

I wish to tell you about another chance encounter in mid-December of 1988 in Dallas during the Texas Symposium on Relativistic Astrophysics. Professor Anandan had graciously made available half of his invited speaker time so that I could have more time to explain in details the result of my computation of the decay rate of black hole resonances formed in high energy collisions of elementary particles, or of the primordial black holes. The latter were thought to be remnants of what was then believed to be a big bang. Jeeva was then already on the faculty in our department. He had informed me at that time that he had expected an opening for a theory position at the University by 1989 or 1990. He encouraged me to take into consideration the unique character of the Foundation of Quantum Theory Group at Carolina with Yakir Aharonov and him as senior members of that group. Everybody who knew Jeeva personally knows how persuasive he could be.

Professor Anandan was a remarkable scientist whose work was widely recognized for the gravitas of his ideas and their experimental confirmations, (for example, the experiment by Werner et al., "Effect of Earth's Rotation on the Quantum Mechanical Phase of the Neutron," *Physical Review Letters,* 42, 001103 [1979]). The detection of Earth's rotation with cold neutron interferometers was a wonderful confirmation of Jeeva's theory of the general relativistic Sagnac effect.

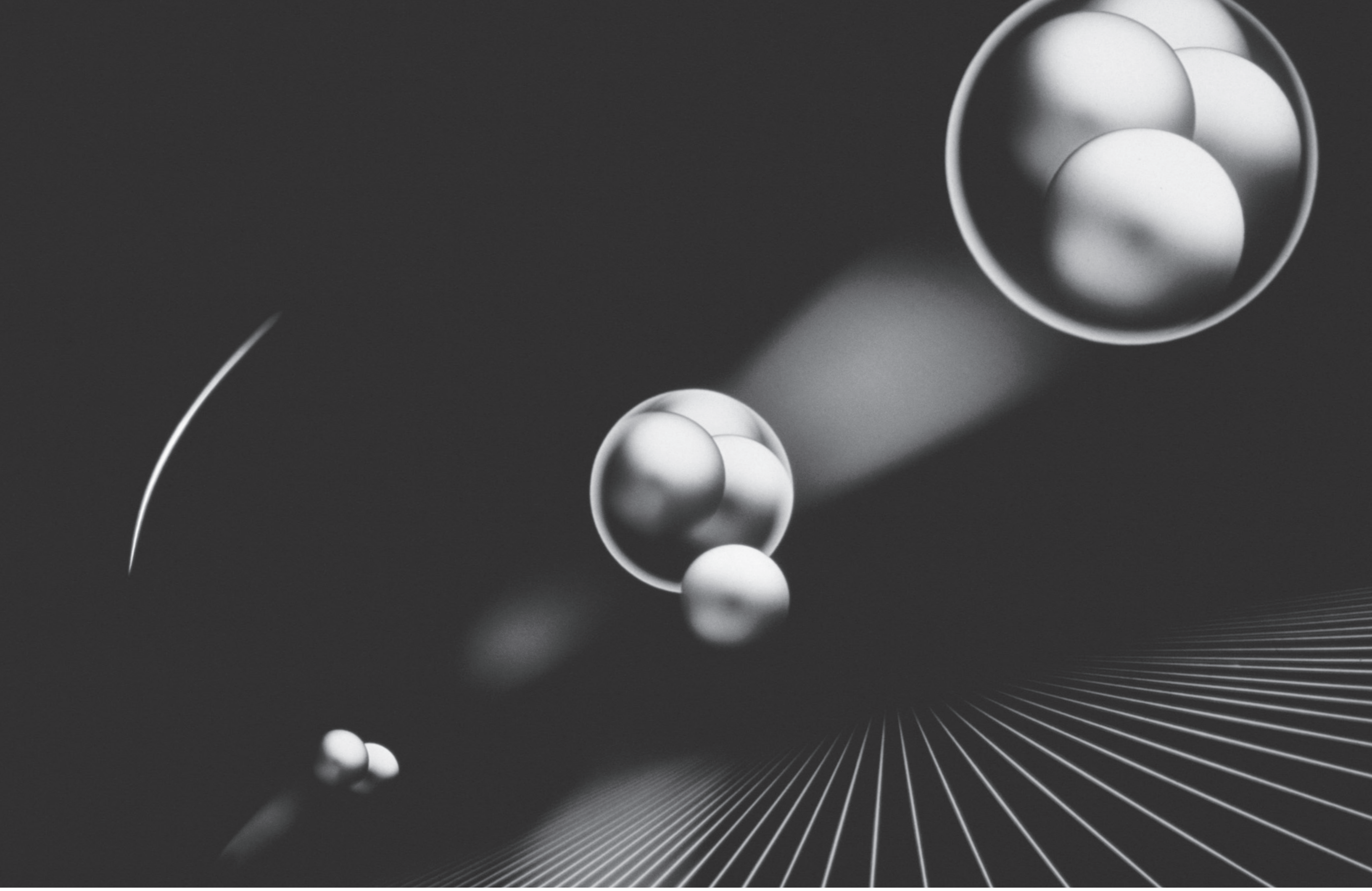
However, in my opinion, of greater relevance here is the beautiful experiment testing general relativistic effects on charged particles by Jain, Lukens, and Tsai (*Phys. Rev. Lett.* 58, 1165 [1987]) that extended the famous Pound and Rebka experiment testing the Einstein redshift formula for static gravitational fields (R.V. Pound and G.A. Rebka Jr., "Apparent Weight of Photons," *Physical Review Letters,* 4, 000337 [1960]) the gamma-rays to extremely long wavelength photons and charged particles. The confirmation of Jeeva's prediction, published in 1984, was at that time the crowning achievement of a mature young theoretical physicist.

What does this tell you about Jeeva's taste for theoretical-mathematical physics? Well, it has told me that his was an unerring higher sense of perception of abstract ideas underlying the subtle mechanisms of nature. Albert Einstein called this "the highest form of musicality in the sphere of thought" when he was referring to Bohr's work.

I learned a lot from Professor Anandan. He had a great taste for theoretical physics, and his intuition was unerring. The choices of research topics show his nose for fundamental questions. He made lasting contributions to theoretical physics. Jeeva's name was well-known to all theoretical-mathematical physicists. It should not come as a surprise to learn that Jeeva had successfully interacted with the truly great theoretical physicists of our times, Professors Yakir Aharonov, Eugene Wigner (Nobel 1963), Chen-Ning (Frank) Yang (Nobel 1957), Norman Ramsey (Nobel 1989), Gerardus`t Hooft (Nobel 1999), Frank Wilczek (Nobel 2004), and many, many others. Professor Yang characterized Jeeva as one of the few most talented young theoretical physicists of his generation.

It would not do justice to Professor Anandan if I did not emphasize the sense of fairness that characterized his gentle personality. Jeeva was very generous to his junior colleagues and students. Our former graduate students Dr. Shenjun Wu and Dr. Jun Suzuki, as well as myself, were deeply influenced by his untimely passing.

Pawel Mazur is a professor of theoretical physics here at the University and a member of the Foundation of Quantum Theory. He wrote this article on the fifth anniversary of Professor Jeeva Anandan's untimely passing.



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08669 University Publications 12/08