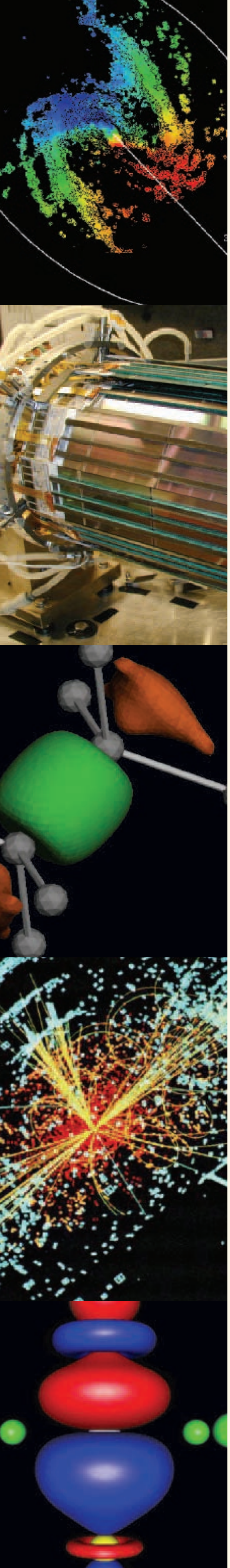

RUTGERS
School of Arts and Sciences

Department of Physics & Astronomy Newsletter

December 2011

INSIDE

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Message from the Chair

I am pleased to be able to bring you our second newsletter as we end the first semester of the 2011-12 academic year. The positive response to our first newsletter was very gratifying and I'm pleased at the number of you who registered at our alumni site, **http://www.physics.rutgers.edu/alumnifriends/.** We will be setting up contact lists at the alumni site in the near future in order to help the large community of friends and alumni of the Rutgers Department of Physics and Astronomy keep in contact with each other. One aspect of this will be to allow recent graduates to benefit from the experiences of past graduates. To facilitate this, I have set up a group on Linkedin ® called Rutgers Physics and Astronomy. If you are a Linkedin user, please join the Physics group.

I look forward to hearing from you and receiving any feedback you might have on items of particular interest to alumni.

Professor Ronald Ransome
Physics & Astronomy Department Chair

NEW FACULTY

The Department was fortunate to have three new professors join our program starting fall semester 2011.

Professor Rachel Somerville

Professor Rachel Somerville joins us as the first **George A. and Margaret M. Downsbrough Chair in Astrophysics.** A generous gift from the estate of Rutgers physics alumnus George Downsbrough (Ph.D. 1936; the second student to earn a doctorate in physics at Rutgers), established the first endowed chair in the Department of Physics and Astronomy. Professor Somerville did her PhD work at UC-Santa Cruz and comes to us from the Space Telescope Science Institute.

Professor Somerville is a world leader in the study of how galaxies form and evolve in the Universe, connecting observations made by powerful telescopes with theoretical insight into the history of cosmos. Observatories like the Hubble Space Telescope have shown galaxies billions of light-years away, at a time when the Universe was billions of years younger than it is today. Understanding how those first galaxies formed, and turned into galaxies like the Milky Way today, in the context of a vast and expanding Universe, is one of the key goals of modern astrophysics. It will be the primary research question to be addressed by NASA's planned James Webb Space Telescope, the successor to the Hubble.

Distant galaxies in the Hubble Space Telescope Ultra Deep Field

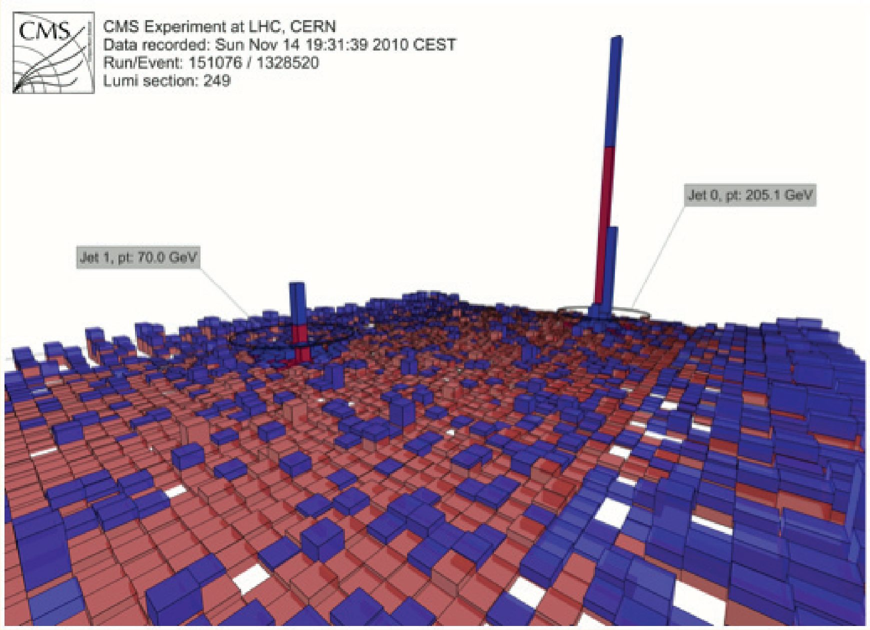
One of the crucial difficulties in this field is connecting things astronomers can see, like the stars and gas of galaxies, to things they can't, like dark matter and dark energy, whose effects nonetheless dominate the Universe on the largest scales. Professor Somerville's research lies at that interface of dark and light, testing models of how galaxies form and evolve by confronting computer simulations with the observations. For example, because dark matter is thought to interact only gravitationally, its behavior on large scales can be predicted through theory and simulation. Normal matter feels the gravitational effects of this dark matter, but it has more interactions: it can heat up or cool down, emit or absorb light, form stars that fuse lighter elements into heavier ones, and release this material back into space, sometimes violently, creating exotic objects like black holes. Many of these processes occur at length scales too small to be probed by even the most advanced cosmological simulations. Professor Somerville's work in "semi-analytic modeling" has led the way in improving the results of these numerical simulations so they can be meaningfully compared with observations. Her arrival at Rutgers has tremendously strengthened the astrophysics group, which has a long history of research in the fields of galaxies and cosmology, and is sure to have an even brighter future.

Professor Sevil Salur joins the Department as an assistant professor in experimental nuclear physics. She received her PhD at Yale, followed by a post-doc at Lawrence Berkeley Lab. Professor Salur's researched is centered on the LHC heavy ion program using the CMS detector, studying matter under extreme conditions.

The protons and neutrons that constitute atomic nuclei are themselves composed of fundamental particles called quarks and gluons (together called partons). In nature we can only observe quarks in the form of hadrons. However, partons behave almost as free particles when they are very close to each other. This surprising phenomenon, called "asymptotic freedom" and honored by a Nobel Prize in 2004, has led to our current theory describing the interactions of particles, Quantum Chromo-Dynamics (QCD). The deconfinement of quarks and gluons to create a new phase of matter, the Quark Gluon Plasma (QGP), is predicted to occur in large energy density ultra-relativistic collisions in the laboratory, as it was present a microsecond after the Big Bang. The challenge of understanding the behavior of nuclear, hadronic and partonic matter at high energy densities requires combining information about the dynamics of these complex collisions with theoretical predictions of high density QCD matter.

Professor Salur did her PhD work with the STAR collaboration at the Brookhaven Relativistic Heavy Ion Collider studying the QGP. They showed at the very high densities present in collisions there that the QGP acted as a nearly perfect liquid. Her experiments at the LHC will study the plasma at even higher energy densities, allowing further studies of matter at extremes of pressure and density.

Professor John Paul Chou joins the Department as an assistant professor in experimental particle physics. He received his PhD at Harvard, followed by a post-doc at Brown and a LHC Physics Center Fellow. Professor Chou works on the CMS detector at LHC studying proton-proton collisions. He joins **Professors Eva Halkiadakis, Yuri Gershtein, Amit Lath, Steve Schnetzer, Sunil Somalwar** and **Scott Thomas** as part of the Rutgers CMS experimental team. Their work was profiled in the June 2011 newsletter.



A dijet event observed by CMS experiment from the first heavy ion collisions at LHC

AWARDS AND HONORS

Professor **Sasha Zamolodchikov** received 2011 Dirac Medal, awarded by the International Centre for Theoretical Physics for his contributions to string theory and condensed matter theory ***http://www.ictp.it/news/2011-dirac-medal.aspx***.

Professor **Eric Gawiser** was awarded a prestigious NSF CAREER award. This is the eleventh CAREER award our young faculty have won since 2004, one of the highest number of any Physics Department in the country.

Many other notable achievements of our faculty, students, and staff can be found at our website ***http://physics.rutgers.edu/physics-news/news.shtml.***

GRADUATE STUDENTS LEAD TA TRAINING EFFORT

At some point during their time as students, nearly all graduate students in the Department of Physics and Astronomy serve as teaching assistants to the hundreds of undergraduates taking physics courses every year, and yet in the past there has been no formal training specific to the demands of teaching physics. In 2010, physics graduate students **Simon Knapen** and **Michael Manhart** and Graduate School of Education student **Heather Briggs** collaborated with the Department to initiate a program to spur the professional development of first-time TA's as physics educators. The program is titled "Developing Educational Leaders among TA's in Physics" (DELTA P), which continues this year under the supervision of faculty sponsor **Professor Eric Gawiser**. The goals of the program are to foster excellence and consistency among graduate student teaching assistants and to strengthen and unify the undergraduate educational experience.

DELTA P consists of two components. The first component is an orientation session held before the fall semester to introduce new TAs to the basics of the department's undergraduate curriculum and their typical duties as TAs such as teaching recitations and labs, grading assignments, and writing quizzes. The second component consists of 10 weekly seminars throughout the fall semester on a variety of more specialized topics. This is intended to expose new TAs to more sophisticated ideas in pedagogy after they have acquired some teaching experience. Speakers at these sessions have included experienced physics TAs, research postdocs with significant teaching experience, physics faculty, education research faculty, and physics instructional staff. Graduate students who successfully complete the program will receive an official credential from the department certifying their training in physics education.

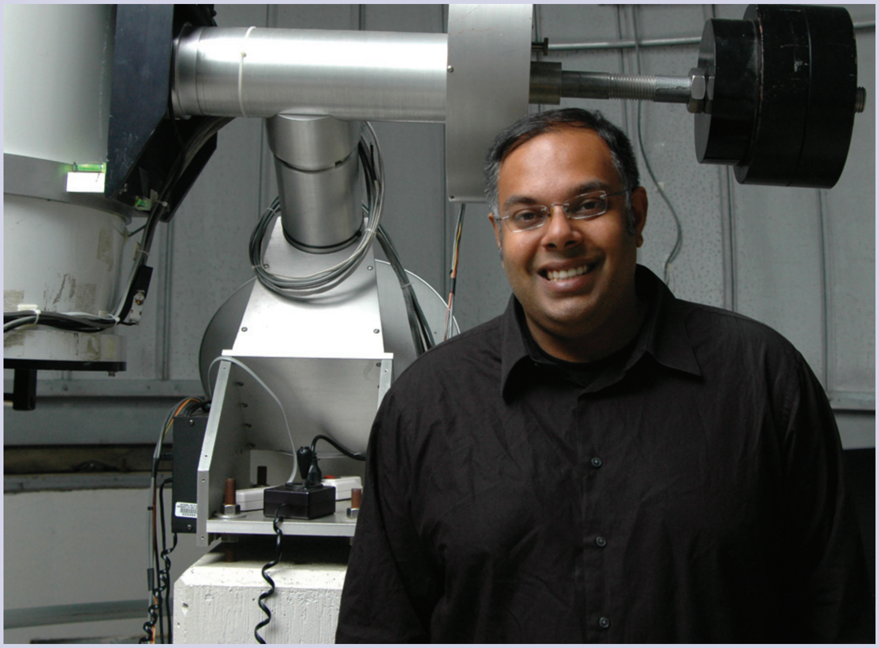
RUTGERS CONNECTION TO 2011 NOBEL PRIZE

The 2011 Nobel Prize in Physics was awarded to Brian Schmidt (Australian National University), Adam Riess (Johns Hopkins), and Saul Perlmutter (UC Berkeley) for the 1998 discovery of the accelerating expansion of the Universe via observations of exploding stars called Type Ia supernovae. The discovery was made by two rival teams, the High-Z Supernova Search Team (led by Schmidt) and the Supernova Cosmology Project (led by Perlmutter).

Rutgers Physics and Astronomy **Professor Saurabh Jha** was a graduate student at Harvard in 1998 and a member of the High-Z Supernova Search Team. Jha was one of twenty co-authors of his team's discovery paper that was cited by the Nobel Prize Committee: "Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant" (Riess ***et al***. 1998, Astronomical Journal, 116, 1009).
Ever since the discovery of the expansion of the Universe by Hubble and Lemaitre in the late 1920s, astronomers have been trying to determine the history of that expansion, set into motion by the Big Bang. Because of the gravitational attraction of all the matter in the Universe, it was widely believed that the expansion should be slowing down with time (decelerating): the greater the cosmic mass density, the more deceleration. If the mass density was above a certain critical value, the expansion would eventually stop and the Universe would begin to contract, resulting in a "Big Crunch". The quest to measure this expected deceleration was at the forefront of cosmology for many decades.

By the mid-1990s, astronomers had identified that type Ia supernovae were excellent "standard candles" with which to measure the history of cosmic expansion. The relatively uniform luminosity of these exploding white dwarf stars meant that observations of how bright they appear could be used to determine their distance, and thus how far back in time they had exploded. After painstaking measurements of these supernovae with the world's best telescopes (on the ground and in space), in 1998 the two teams reached the surprising conclusion that the expansion of the Universe was not slowing down at all, but rather speeding up!

This discovery ushered in a revolution in our understanding of cosmology. Explaining the accelerating Universe


Professor Saurabh Jha

in the standard cosmological framework (based on Einstein's theory of gravity: general relativity) requires some form of "dark energy" to drive the acceleration. One possibility was suggested (but discarded) by Einstein himself: the cosmological constant, the idea that the "empty" space itself has a vacuum energy density and a tendency to expand, pushing apart the galaxies faster and faster. This is one of the deepest mysteries in all of physics, and understanding the origin of the accelerating Universe (whether it is the cosmological constant, some other energy field pervading the Universe, or a more fundamental mistake in our understanding of gravity) is at the forefront of modern cosmological research.

Now at Rutgers, Professor Jha continues to study type Ia supernovae in order to make them more precise and accurate distance indicators, and to distinguish between different possibilities for dark energy. With his students, Jha is using Rutgers' share of the Southern African Large Telescope to observe type Ia supernovae, and is taking advantage of Rutgers' participation in the upcoming Large Synoptic Survey Telescope, which will discover hundreds of thousands of supernovae and refine understanding of dark energy. Prof. Jha continues to collaborate with Nobel Laureates Riess and Schmidt, and will take part in the team's celebration at the Nobel Prize Award Ceremonies in Stockholm this December.

The type Ia supernova 1994D (bright star on the lower left) in a nearby galaxy

UNDERGRADUATES FOUND RUTGERS ASTRONOMICAL SOCIETY

Although the Department has long held public viewings with the 20″ telescope housed in the viewing dome atop Serin Physics Labs, there has never been a more formal amateur astronomer organization. That changed in January 2011 when the Rutgers Astronomical Society was founded by a group of undergraduates led by **Viraj Pandya.** The Society has established affiliations with longstanding local organizations such as the Amateur Astronomers Association of Princeton, Amateur Astronomers, Inc., and the South Jersey Astronomy Club, and was also invited to join the United Astronomy Clubs of New Jersey alliance.

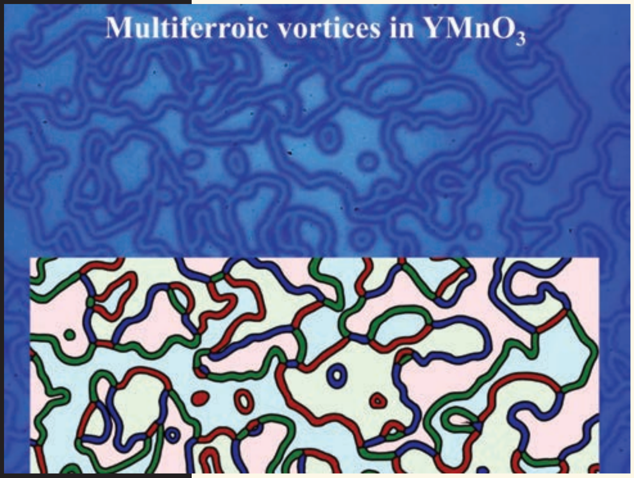
Using funds from the alumni donors for the general use by the Department, four 8″ telescopes were purchased for the use of the Society. The Society has been able to hold observing sessions on the roof of the Serin Physics & Astronomy Building for the Rutgers University community and the general public. The club was also asked by the Orange Public Library in Orange, NJ to cosponsor an International Observe the Moon Night event, for which three telescopes were set up to let young children experience the remarkable view of the Moon through a telescope. The Society will be working to add a star party component to the well-known Faraday Lecture, and it is due to this event that the idea for the proposal was first conceived. Several telescopes will be set up during and after the Faraday Lecture to provide visitors with three nights of stargazing and the opportunity to get breathtaking views of celestial objects.

DEPARTMENT FIRST TO MEET ENDOWED CHAIR CHALLENGE

In September 2011, an anonymous donor pledged $27 million to endow 18 chairs at Rutgers University. The donor provided half the required $3 million for each chair, with the condition that the other $1.5 million for each chair be provided by other donors. In November, 2011 the Department of Physics and Astronomy became the first to receive a matching pledge, when **Professor Claud Lovelace** agreed to provide the matching funds. Professor Lovelace is a well known high energy theorist, and one of the founders of string theory. Professor Lovelace has specified that the chair should be in experimental condensed matter physics.

RESEARCH NEWS

Condensed Matter:



An intriguing ferroelectric domain pattern of multiferroic hexagonal YMnO3: optical microscope image of the surface of a chemically-etched crystal. The pattern is associated with the emergence of Z3xZ3 symmetry, which is represented by proper domain coloring with three bright colors and three dark colors —"bright domains hold downward polarization domains while dark domains hold upward polarization. Six domains merge always at one point, which becomes the basis of a ferroelectric vortex.

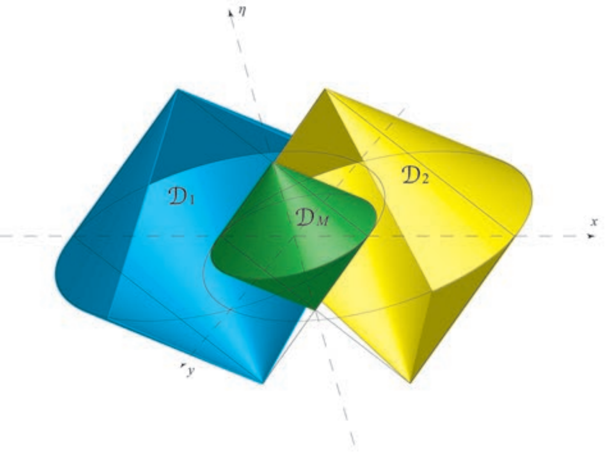
Maxwell's equations tell us that magnetic interactions and motion of electric charges, which were initially thought to be two independent phenomena, are intrinsically coupled to each other. In the covariant relativistic form, they reduce to just two equations for the electromagnetic field tensor, succinctly reflecting the unified nature of magnetism and electricity. The formal equivalence of the equations of electrostatics and magnetostatics in polarizable media explains numerous similarities in the properties of ferromagnets, which have a spontaneous magnetic polarization, and ferroelectrics, which have a spontaneous electric polarization. These similarities are particularly striking in view of the seemingly different origins of ferroelectricity and magnetism in solids: whereas magnetism is related to ordering of spins of electrons in incomplete ionic shells, ferroelectricity results from relative shifts of negative and positive ions that induce surface charges. Magnetism and ferroelectricity coexist in materials called multiferroics. The search for these materials is driven by the prospect of controlling charges by applied magnetic fields and spins by applied voltages, and using this property to fabricate new multifunctional devices. Much of the early work on multiferroics was directed towards bringing ferroelectricity and magnetism together in one material. This proved to be a difficult problem, as these two contrasting order parameters turned out to be mutually exclusive. Furthermore, it was found that the simultaneous presence of electric and magnetic dipoles does not guarantee strong coupling between the two, as microscopic mechanisms of ferroelectricity and magnetism are quite different and do not strongly interfere with each other. About five years ago, it was recognized that ferroelectricity naturally arises when the crystallographic lattice follows magnetic lattice with broken spatial symmetry below a magnetic transition temperature, and in these magnetism-driven ferroelectrics, applied magnetic fields can induce collective magnetic phase transitions that subsequently induce huge changes of dielectric and ferroelectric properties. **Professor Sang-Wook Cheong,** with R. Ramesh (UC Berkeley) and N. Spaldin (UC Santa Barbara by then), were awarded the James C. McGroddy Prize for New Materials sponsored by American Physical Society for this discovery.

Professors Cheong, Valery Kiryukhin, and **Weida Wu** are leading experimental efforts to better understand multiferroics, in collaboration with **Professors Rabe** and **Vanderbilt** on the theory side. One of their contributions is the discovery of topological vortices in a multiferroic. The fascinating concept of topological defects permeates ubiquitously our understanding of the early-stage universe, hurricanes, quantum matters such as superfuids and superconductors, and also technological materials such as liquid crystals and magnets. In the process of continuing multiferroics research, Professor Cheong, in collaboration with **Yoichi Horibe** and Professor Wu, has discovered the so-called multiferroic vortices. Hexagonal REMnO3 (RE= rare earths) with RE-Ho-Lu, Y, and Sc, is an improper ferroelectric where the size mismatch between RE and Mn induces a trimerization-type structural phase transition, and this structural transition leads to three structural domains, each of which can support two directions of ferroelectric polarization. They found that domains in h-REMnO3 meet in cloverleaf arrangements that cycle through all six domain configurations. Occurring in pairs, the cloverleafs can be viewed as vortices and antivortices, in which the cycle of domain configurations is reversed. Vortices and antivortices are topological defects: even in a strong electric field they won't annihilate. These ferroelectric vortices/antivortices are found to be associated with intriguing magnetism. In addition, they found that the seemingly-irregular configurations of a zoo of multiferroic vortices and antivortices in h-REMnO3 can be neatly analyzed in terms of graph theory and this graph theoretical analysis reflects the nature of self-organized criticality in complexity phenomena as well as the condensation and eventual annihilation processes of topological vortex-antivortex pairs.

High Energy Theory:

For about a decade, **Professor Thomas Banks** has been working on a theoretical framework called Holographic Space-time (HST), which generalizes string theory to take into account the cosmology of the real world. String theory has proved inadequate to discussing both the beginning and the long term future of the universe. The two basic principles of HST are that space-time is defined by its information content (the number of bits needed to describe it) and that each observer has its own description of physics. Space-time as a whole is reconstructed by insisting on consistency between the descriptions of physics of different observers. The traditional formalism of quantum field theory (QFT) assigns independent interacting degrees of freedom to each point of space and insists on a global description of all of these systems. It is inadequate for describing the quantum mechanics of situations where black holes are formed. Moreover, in HST the information available to a given observer during a finite proper time is finite, whereas in QFT it is infinite. This resolves all of the problems of traditional approaches to the quantum mechanics of the gravitational field.

HST also incorporates Supersymmetry in a fundamental way. Supersymmetry (SUSY) is a hypothetical symmetry relating force particles like photons, to matter particles, analogous to electrons but with zero charge. If this symmetry were restored at energies around those being explored by the LHC at CERN it would remove certain problems of fine tuning of parameters in the Standard Model of particle physics. Supersymmetry has also been found to be a property of all rigorously defined models of string theory in space-times of low curvature. So far, none of the SUSY partners of the particles we know have been found experimentally, but they are one of the main targets for the LHC searches. HST shows that SUSY is rigorously correlated with the low curvature of space-time, and predicts a relationship between that curvature and the masses of the SUSY partners. Over the past 15 years, astronomers have measured the large scale curvature of space-time through the observation of distant supernovae and of the cosmic microwave background radiation. The HST relation then predicts that super partners must be found at the LHC. Combining this relationship with some broad facts about particle phenomenology, one is led to a complete model for physics in the LHC energy range and slightly beyond it, with a rather small number of parameters.



The two causal diamonds $\mathcal{D}_1$ and $\mathcal{D}_2$ (z spatial coordinate suppressed) and the maximal causal diamond $\mathcal{D}_M$ that fits in the intersection $\mathcal{D}_1 \cap \mathcal{D}_2$

ALUMNI ACHIEVEMENTS

As a regular feature of this newsletter, we will feature some notes on our alumni and the wide variety of careers they have had. For our spring 2012 newsletter we would like to updates on alumni from the classes of 1952, 1962, 1972, 1982, 1992, and 2002. Please send information on yourself to Professor Ransome (*chair@physics.rutgers.edu*) for inclusion in the next issue or posting on the alumni page of our website. This issue features two alumni from the classes of 1962 and 2002.

From the class of 1962 we have **Donald L. Lehman.** Don started at Rutgers in electrical engineering but after a great sophomore course taught by Professors Weidner and Sells, he switched to physics. After completion of his bachelors at Rutgers, he went on to earn his Ph.D. from George Washington University in 1970 and later joined GW as a professor of nuclear theory, eventually being named George Gamow Professor of Theoretical Physics. He became Executive Vice President for Academic Affairs in 1996. Don retired from GW at the end of 2011. He recently moved to Williamsburg and will continue his research in collaboration with faculty members at William and Mary.

Sonja Dieterich graduated with a PhD from Rutgers in 2002. Sonja's Ph.D. was in nuclear physics under the direction of Professor Ransome, but after graduation she switched to medical physics and took a post-doc at Georgetown University. She moved to Stanford University Hospital in 2007 and is now Director of Radiosurgery Physics.

GIVING

I have shared with you just some of the tremendous accomplishments of our faculty and students. Yet our Department faces serious challenges in maintaining quality education, research and outreach programs in light of the economic climate in our state and nation. Do not hesitate to contact me to learn more about how you could help address some of the Department's needs. To help support the education, research, or outreach activities of the Department, you can also make secure contributions on the "Giving to Physics & Astronomy" page on the web site, *http://physics.rutgers.edu.*

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p. 3 courtesy of CMS; p. 4 Miguel Acevedo, High-Z Supernova Search Team; p. 6 S.W. Wong; p. 7 Tom Banks