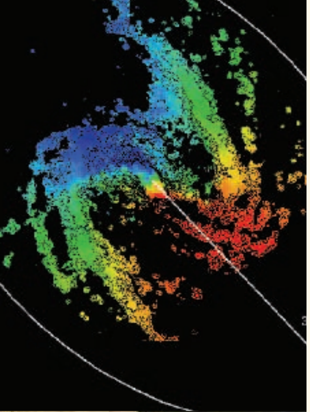
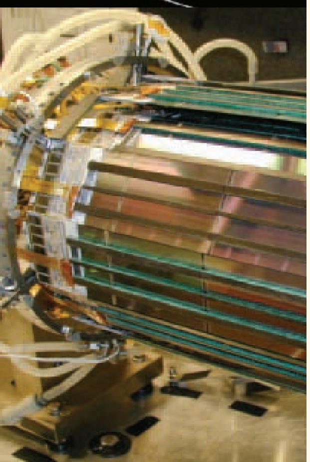
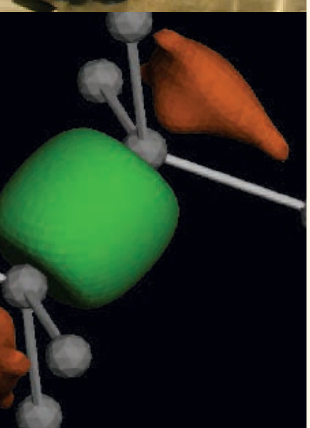
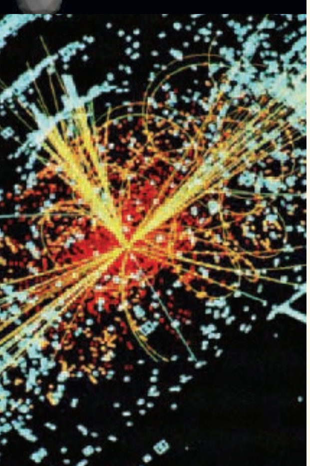
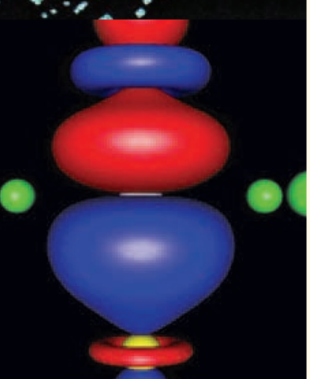










RUTGERS
School of Arts and Sciences

December 2012

Department of Physics & Astronomy Newsletter

Message from the Chair

I am pleased to be able to bring you news of the Department as we end the first semester of the 2012-13 academic year. I hope you enjoyed our previous newsletters. One goal is to help bring together our alumni and establish a vibrant community of past and present Department friends and alumni. Many of you have already registered at our alumni site, *http://www.physics.rutgers.edu/alumnifriends/*. I hope many more of you will register, and connect with us at Linkedin® site called Rutgers Physics and Astronomy. If you have suggestions or contributions for future newsletters, please contact me at *chair@physics.rutgers.edu*.

Professor Ronald Ransome
Physics & Astronomy Department Chair

INSIDE

Department of Physics and Astronomy
Rutgers, The State University of New Jersey
136 Frelinghuysen Road
Piscataway, NJ 08854-8019
www.physics.rutgers.edu

THE LOVELACE DONATION

Professor Claud Lovelace, who passed away in September, has willed his entire estate, with a value of approximately $4 million, to the Department of Physics and Astronomy. Professor Lovelace was the first to pledge matching funds to the $27 million challenge grant of an anonymous donor, who funded half of 18 endowed chairs at Rutgers. The endowed chair will be in experimental condensed matter physics. In addition, Professor Lovelace endowed a startup fund for new faculty in experimental condensed matter physics, and a graduate fellowship, without restriction to area of research. The Lovelace Chair will be the second endowed chair for the Department, following the Downsbrough Chair, and the graduate fellowship will be the Department's first endowed fellowship. He also donated his John Challis clavichord to Mason Gross School of the Arts.

WILLIAMS TO LEAD SAAO

Ted Williams

Professor Ted Williams, a member of the Department since 1979, will become one of the top astronomy officials in South Africa's national government. He has been appointed director of the South African Astronomical Observatory (SAAO), which oversees the nation's optical observing facilities, including the Southern African Large Telescope (SALT). The SAAO's mission is to conduct research, maintain state-of-the-art facilities and instrumentation, and promote astronomy and astrophysics throughout southern Africa.

Williams will take a leave of absence from Rutgers beginning in January and move with his wife and four dogs to SAAO headquarters in Cape Town, where they will live in the director's home on a historic campus that was once the Royal Observatory, the first scientific institute in Sub-Saharan Africa.

Rutgers was a founding member of SALT, and Rutgers astronomers currently have a 10% share of observing time with the telescope. With Professor Williams taking the leadership of SAAO, the Rutgers-SALT collaboration becomes even stronger.

If you or someone you know would like to learn more about the research and educational activities that Rutgers astronomers are involved in, about SALT or about public astronomy-related events at Rutgers, please check out the "Friends of Rutgers Astronomy" group at *http://astronomy.rutgers.edu/friends*.

AWARDS AND HONORS

Senior astrophysics major **Benjamin Forrest,** class of 2012, won one of two *2011-12 American Eagle Outfitters Michael Tranghese Postgraduate Leadership Awards* given across the entire BIG EAST Conference. The Tranghese Award honors academic excellence and comes with a $5000 scholarship that can be applied to postgraduate study, in Forrest's case at Texas A&M University, where Ben is pursuing a Ph.D. in astrophysics.

Physics major **Kelvin Mei**, class of 2013, won the highly prestigious *Barry Goldwater Scholarship*. The scholarship is awarded annually to 275 students across the nation, across all of the natural sciences, math, and engineering.

Professor David Shih of the Department of Physics & Astronomy and New High Energy Theory Center has won a *Sloan Fellowship*. The Sloan recognizes the most promising young researchers in America. Over 30 Sloan Fellows have later gone on to win Nobel Prizes. David is the only winner from Rutgers this year, and joins Professors Emmanuel Diaconescu, Kristjan Haule, Emil Yuzbashyan, Alex Morozov, and Valery Kiryukhin to make six Sloan winners in our Department since 2001.

Professor Weida Wu has won a *DOE Early Career Award*. The five-year awards are designed to bolster the nation's scientific workforce by providing support to exceptional researchers during the crucial early career years, when many scientists do their most formative work. Weida also won an NSF CAREER award.

Professor Terry Matilsky has won the *Richard H. Emmons Award* from the Astronomical Society of the Pacific, which is awarded annually to an individual demonstrating outstanding achievement in the teaching of college-level introductory astronomy for non-science majors.

Professor Jerry Sellwood has won the *Dirk Brouwer Award* from the Division of Dynamical Astronomy of the American Astronomical Society. The Brouwer Award recognizes outstanding contributions to the field of dynamical astronomy, including excellence in scientific research, impact, and influence in the field, and excellence in teaching and training of students.

Professors Eva Andrei and **Sasha Zamolodchikov** have been elected to membership in the *American Academy of Arts and Sciences*. The AAAS is one of the nation's most prestigious honorary societies and a leading center for independent policy research. Founded in 1780, the AAAS counts more than 200 Nobel Prize laureates and 100 Pulitzer Prize winners among its fellows. They join Greg Moore and Tom Banks to make 4 members of our Department in the AAAS.

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

RESEARCH NEWS

Astronomy

"How does structure form in the Universe?" "How do galaxies acquire their beautiful shapes?" "What is dark matter?" These are the questions that literally keep astronomers up at night. When it comes to the formation of cosmic structures, gravity, acting on mass, is the driving force. Regions of the early Universe that were originally slightly overdense grow denser with time, while underdense regions become more tenuous. This is how the Universe that we observe today came to be filled with galaxies, clusters, and superclusters arrayed in a beautiful complex pattern of filaments, sheets, and voids known as the "cosmic web."

Over the last half-decade, astronomers at Rutgers have been engaged in a remarkable program of discovery using the Atacama Cosmology Telescope (ACT), an international collaboration with colleagues at Princeton, the University of Pennsylvania, and other institutions across the US, Canada, South Africa, and Chile. ACT collects millimeter-wavelength radio waves of the cosmic microwave background (CMB) radiation. To minimize absorption by atmospheric water vapor, ACT was sited in the Atacama desert of northern Chile, one of the driest places on Earth. At an altitude of nearly 5200 m, ACT is also one of the highest, permanent, ground-based astronomical observatories in the world.

Rutgers astronomers involved with ACT are particularly interested in galaxy clusters, the largest objects in the universe that are held together by gravity. They form through the merger of smaller groups or sub-clusters of galaxies. Because the formation process depends on the amount of dark matter and dark energy in the Universe, clusters can be used to study these mysterious phenomena. Dark matter is material that can be inferred to exist through its gravitational effects, but does not emit and absorb detectable amounts of light. Dark energy is a hypothetical form of energy that permeates all space and exerts a negative pressure that causes the universe to expand at an ever-increasing, accelerating, rate.

ACT reveals galaxy clusters through the Sunyaev-Zeldovich effect. In this phenomenon, photons in the cosmic microwave background inverse Compton scatter off electrons in the hot gas that pervades these enormous galaxy clusters. This boosts the photon energy, which distorts the signal from the microwave background in the direction of the clusters. The magnitude of this distortion depends on the density and temperature of the hot electrons and the physical size of the cluster. Based on three full seasons of observations from 2008 through 2010, ACT now has a sample of nearly 100 massive galaxy clusters. **Felipe Menanteau** (Rutgers Research Associate) and **Jack Hughes** (Rutgers Faculty) are using large ground-based optical telescopes in Chile (Gemini-South and ESO's Very Large Telescope) as well as space-based telescopes (the Chandra X-ray Observatory and the Hubble Space Telescope) to get to the heart of what matters most for these clusters — namely how much mass they contain.

In the course of this work, Menanteau and Hughes came across a truly exceptional cluster. Officially known as ACT-CL J0102–4915, it is located more than seven billion light years from Earth. This large distance means that it is being observed at a young age, when the Universe was barely half as old as it is now. Using several different independent measurements, Menanteau and Hughes calculated a mass for the cluster of 2 quadrillion (2 × 1015) times the mass of the Sun, making it the most massive of any known cluster at its distance or beyond. To mark this distinction, while giving a nod to the Chilean connection, the researchers nicknamed the cluster "El Gordo" meaning "the big one" or "the fat one" in Spanish. El Gordo is superlative in more ways than its mass: it is the hottest, most X-ray luminous and brightest Sunyaev-Zeldovich effect cluster in the distant Universe.

Although a cluster of El Gordo's size at that distance is extremely rare, it is likely that its formation can be understood in terms of the standard Big Bang model of cosmology, in which the universe is composed predominantly of dark matter and dark energy and has been expanding for 13.7 billion years.

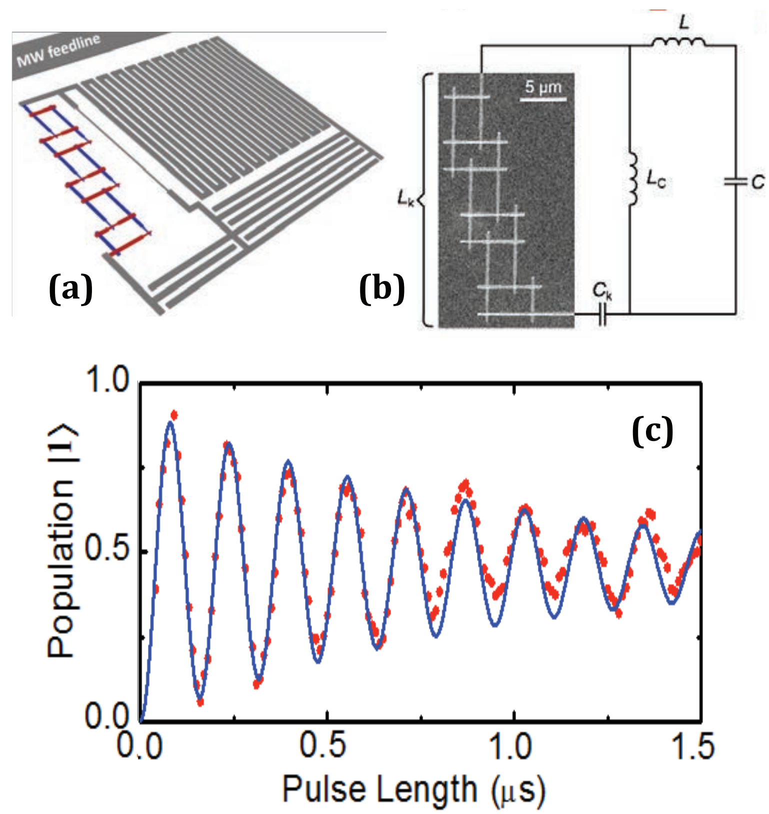
Delving deeper into the data from Chandra and the Very Large Telescope, Menanteau and Hughes showed that El Gordo is, in fact, undergoing a major merger between two nearly equal sub-clusters. Their observations caught El Gordo soon after the two merging components passed through each other. During a merger, the cluster galaxies mostly whiz by each other (stellar collisions are rare) while the cluster gas, behaving as a fluid, experiences shocks, viscosity, and ram pressure that impede its motion. This difference in the physical processes acting on the gas and galaxies causes a spatial offset between the two, an effect which Menanteau and Hughes showed to be present in El Gordo.

We know little about the nature of dark matter, but the question "Does dark matter have interactions with itself (other than gravity)?" can be addressed by merging clusters. If the dark matter is collisionless (as we suspect), it should follow more closely the post-merger distribution of galaxies than the gas. So by studying how far apart the gas, galaxies, and dark matter are in a post-merger cluster like El Gordo, astronomers can begin to constrain a basic property of the dark matter. Menanteau and Hughes have in hand recently acquired data from the Hubble Space Telescope that will allow them to map the location of dark matter in El Gordo, using a technique known as gravitational lensing, an effect predicted by Einstein from his general theory of relativity, in which the matter (dark or not) in a cluster causes the light from background galaxies to be distorted. It is fitting that the remarkable cluster El Gordo may have remarkable applications, helping astronomers "shed light" on the nature of dark matter.

A combined visible-light and X-ray image of the merging galaxy cluster "El Gordo". Superimposed on the reddish optical light of hundreds of galaxies making up the cluster is data from the orbiting Chandra X-ray Observatory (shown in blue). The X-ray emission results from gas heated to extreme temperatures in the cluster's deep gravitational potential well, dominated by dark matter.

Condensed Matter

Recently a team of researchers at Rutgers (Bell, Sadovskyy, Ioffe, and Gershenson) and Caltech (Kitaev) reported on successful realization of a novel concept of a "superinductor," a dissipationless superconducting circuit with a microwave impedance exceeding the resistance quantum $R_Q=h/(2e)^2$. The superinductor is implemented as a specially designed one-dimensional "ladder" of nanoscale Josephson junctions [1]. The inductance of this micron-size device can be very large, greater than that for a several-meter-long wire! The magnitude of the inductance and its nonlinearity can be easily tuned by a weak magnetic field. These properties open new possibilities for the development and controllable coupling of high-performance superconducting qubits, the fundamental units of information in a quantum computer. The Josephson ladder, being connected to a capacitor, can operate as a qubit with a respectably long coherence time exceeding 1 µs. More exciting applications are expected to come, ranging from the fault tolerant quantum computing with superconducting qubits to new electrical current standards, based on Bloch oscillations.



Panel (a): **The on-chip circuit layout of the tested device (the superinductor is shown in color) inductively coupled to the microwave (MW) feedline.** ***Panel (b):*** **The circuit diagram of the superinductor and L_C resonators coupled via the kinetic inductance LC of a narrow superconducting wire. The micrograph shows a ladder with six unit cells.** ***Panel (c):*** **Rabi oscillations of the population of the first excited level of the superinductor resonator. The phase shift of the LC resonance was measured while the superinductor resonator was excited by the second-tone pulsed microwaves.**

It is envisioned that these novel Josephson ladders can be used as a new platform for the study of quantum phase transitions (QPT). By tuning an external parameter (the magnetic field), one can induce spontaneous symmetry breaking in the ladders. The low-energy physics of these arrays close to the QPT can be mapped to the ϕ^4 model that is relevant to a wide spectrum of physical phenomena, from quark confinement to ferromagnetism. Near the critical point, this model shares many common features with the integrable model of a one-dimensional (1D) Ising spin chain in the transverse magnetic field, which serves as a paradigm in the context of nonequilibrium thermodynamics and quantum critical phenomena.

Though the 1D Ising and ϕ^4 models are believed to be relevant to a broad range of physical systems, their experimental realization in well-controllable and tunable systems poses a challenge. Only a few solid-state quasi-1D spin systems can be continuously tuned across the QPT. The novel experimental platform compares favorably with these systems: the exchange interactions between nearest-neighbor "spins" in the ladder can be engineered in order to explore the effect of disorder and phase boundaries.

1. M.T. Bell, I.A. Sadovskyy, L.B. Ioffe, A.Yu. Kitaev, and M.E. Gershenson, Quantum Superinductor with Tunable Non-Linearity, Phys. Rev. Lett. 109, 137003 1-5 (2012).

Elementary Particle Physics

Rutgers particle physicists got an early start to their Fourth of July holiday last July by watching a 3 a.m. webcast from Switzerland that unveiled a discovery to which they had made major contributions: a subatomic particle consistent with the long-sought Higgs boson.

Rutgers participants in the Higgs and related searches at the LHC include faculty members John Paul Chou, Yuri Gershtein, Eva Halkidakis, Amitabh Lath, Steve Schnetzer, Sunil Somalwar, and Scott Thomas. They also include senior scientist Robert Stone and another dozen or so postdoctoral researchers, graduate students and undergraduates. They are members of the CMS experiment, one of two large detectors that reported the new boson discovery.

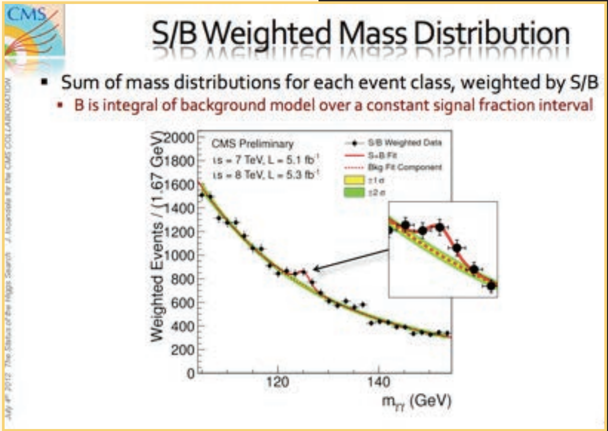
Lath, Thomas, and several colleagues attended the Geneva webcast at a "pajama party" held at the Institute for Advanced Study in Princeton. It was one of many post-midnight gatherings at universities around the country.

Dubbed the "God particle" in a book by Nobel laureate Leon Lederman, the Higgs boson is said to confer mass upon all the matter in the universe. Scottish physicist Peter Higgs and others postulated it almost 50 years ago. Of all the pieces that make up the so-called "Standard Model" of particle physics, this boson has been most elusive.

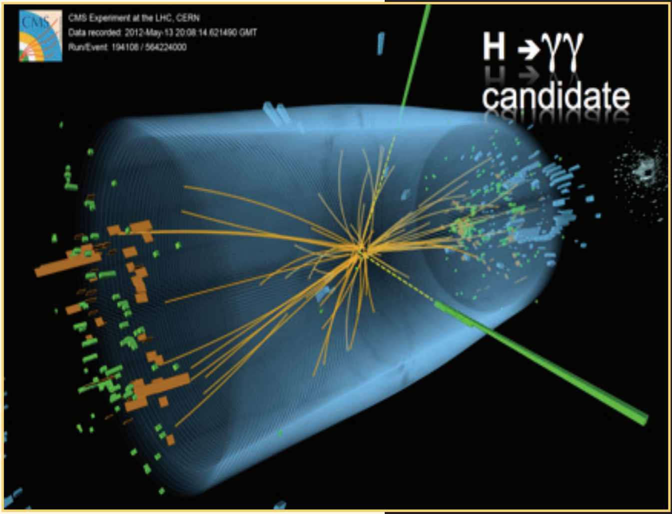
The carefully worded announcement, in which scientists declare they've seen a new particle but cautiously label their discovery as merely "consistent with" the Higgs boson, might leave laypeople scratching their heads, but physicists are excited about the news.

The search in earnest for the Higgs boson began more than a decade ago at Fermilab, where Rutgers physicists joined a worldwide team to study proton-antiproton collisions at the Tevatron, a four-mile ring buried under the Illinois prairie west of Chicago. They stepped up their search in 2008 at CERN, the European Organization for Nuclear Research, examining proton-proton collisions in the more powerful 17-mile Large Hadron Collider (LHC) beneath the mountains of France and Switzerland near Geneva.

Since 1995, Rutgers has made major contributions to constructing and operating the detector, as well as analyzing the data that holds clues of the Higgs. Rutgers involvement includes developing electronic chips for a 60 megapixel silicon detector that captures ionization tracks of particles coming from the collisions. For the Higgs search, Rutgers had a major role in the analysis that found evidence of the Higgs through the "diphoton" channel, in which the Higgs particle decays to two photons. Higgs decay to photons is quite rare, but when it happens, the signature is much easier to discern amid the "noise" of collision debris than the more typical decay route to particles known as W and Z bosons. The CMS Higgs search in the diphoton channel is carried out by three independent analysis groups, one of which is led by Rutgers.

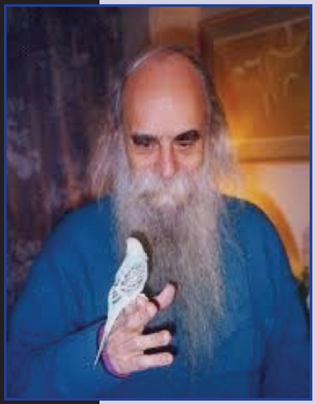


Invariant mass of two isolated photons in the CMS detector, showing a clear excess near m=125 GeV/c_2. Members of the Rutgers group contributed to this analysis.



An event collected by the CMS detector in the Large Hadron Collider that shows a particle collision resulting in two isolated photons, a possible signature of Higgs decay.

Richard Plano



Claud Lovelace

TRANSITIONS

The past year was an exceptionally good year for younger faculty. Six assistant professors were promoted to associate professor with tenure: **Andrew Baker, Eric Gawiser, Eva Halkiadakis, Saurabh Jha, Alex Morozov,** and **Vitaly Podzorov**. In addition, **Kristjan Haule** and **Scott Thomas** were promoted from associate professor to full professor.

This year also saw the passing of **Professor Emeritus Richard Plano** on January 8, 2012, and **Professor Claud Lovelace,** on September 7, 2012.

Richard Plano joined Rutgers in 1960 and was one of the founders of the high energy physics experimental program at Rutgers. He supervised 13 Ph.D. students during his career at Rutgers, and published more than 200 papers in refereed journals. He was a leader in the effort to bring high performance computing to the Department. Professor Plano retired from the University in 1999.

Claud Lovelace joined Rutgers in 1971. He was best known as one of the founders of string theory. Professor Lovelace was devoted to physics and continued to work on developing a "theory of everything" until his death. He was also well known for raising parakeets, and for his extensive classical music collection. As noted on page one, he left his entire estate to the Department, for which we are immensely grateful.

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*. Thank you so very much.

Photo credits:
Front cover Jeremy Sellwood, Amit Lath, David Vanderbilt; p. 2, C. Joseph;
p. 4, F. Menanteau, J. Hughes; p. 6, M. Gershenson; p. 7, A. Lath, C. Blesch;
p. 8, courtesy of R. Plano and C. Lovelace