Greetings and Happy New Year! This past year marked the completion of our new Physics and Astrophysics building next door to Varian Physics. We invite those of you who have not seen our new building, or the new Physics Main Office adjacent to it, to stop by campus for a visit. The Physics and Astrophysics building houses both Kavli and HEPL activities, as well as the teaching laboratories. We are very pleased with the new construction, which will allow for much needed expansion and increased productivity for the future.

This past fall, we were happy to welcome new faculty member Risa Wechsler as a joint Assistant Professor in the Department of Physics and SLAC. Prof. Wechsler was a Hubble Fellow and Enrico Fermi Fellow at the Kavli Institute for Cosmological Physics at the University of Chicago. Her research interests are primarily in the areas of theoretical cosmology and galaxy formation. Risa’s work has involved making detailed predictions for the evolution of structure in cold dark matter models, studying the assembly history and clustering of dark matter halos and galaxies, galaxy formation modeling, and the use of galaxies and clusters as probes of cosmology and fundamental physics. A primary focus of her work has been to make theoretical predic-

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New faculty appointee, Risa Wechsler

Professor David Griffiths Visits Stanford

David Griffiths of Reed College gave a lecture for the Society of Physics Students this past December. Thirty undergraduate physics majors and a smattering of graduate students and faculty attended, eager to meet the author of their favorite textbooks. Professor Griffiths discussed the charge distribution on two-dimensional and one-dimensional conductors, and results for force laws other than the inverse-square law. Emboldened by the genial speaker, students asked questions on a variety of topics: How does one become a good teacher? What makes some physicists famous? And how will the future discoveries in physics compare to those of the past? Many students took the opportunity to have their textbooks autographed by the award-winning educator. David Griffiths will return to Stanford this spring to work on the second edition of his particle physics textbook and co-teach Physics 121 (Intermediate Electricity & Magnetism).

Professor John W. Harris: the 2007 Robert Hofstadter Memorial Lecturer

We are pleased to announce that the annual Robert Hofstadter Memorial Lectures will be given this year by John W. Harris, Professor of Physics and Group Leader of the Relativistic Heavy Ion Group at Yale University. Professor Harris is a Fellow of the American Physical Society, was voted one of the top 40 Distin-
Hofstadter Lecture
---- from page 1

John W. Harris

Committee of the Institute of Nuclear Theory at the University of Washington.

The Hofstadter lectures are scheduled for Monday, April 30, 2007 (an evening public lecture at 8:00 PM) and Tuesday, May 1 (an afternoon colloquium at 4:15 PM). Both lectures will be held at Stanford University, and we hope that you will plan to attend.

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John W. Harris

It's hot – at an absolute temperature of $10^{12}$ K – one hundred thousand ($10^5$) times hotter than the center of the sun. It's runny – runnier than anything known to man – even superfluids. What is it made from – its ingredients? Tiny quarks and gluons. Where did it come from? It's nothing ever made by man, it existed ten millionths ($10^{-5}$) of a second after the beginning of the Universe or about thirteen billion years ago. Can we figure out how to make it – is there a recipe? Yes, we have and we are cooking it up right now. It's a Quark Soup.

I will address these and other questions about the recent creation of a primordial quark soup in the laboratory. Why would we even want to cook it up? What does this soup taste like? It seems to have a unique flavor – has anyone ever really sampled a soup of quarks and gluons? Perhaps there is a secret ingredient? And by the way – what is that tiny Black Hole doing in my Quark Soup?

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Ultra-relativistic collisions of heavy nuclei are being investigated for the first time at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and will soon be investigated at the Large Hadron Collider at CERN. These collisions heat nuclear matter to energy densities previously reached only within the first few microseconds after the Big Bang. Temperatures of $2 \times 10^{12}$ K are reached, melting the vacuum into a plasma of quarks and gluons. The goal of physicists in this field is to re-create and uniquely identify properties the primordial quark-gluon plasma in order to understand Quantum Chromodynamics at high energy densities. After six years of operation, RHIC and its experiments have established the presence of such extreme energy densities, temperatures and pressures. The system that is created behaves somewhat unexpectedly as a strongly-interacting, low viscosity liquid of quarks and gluons and is opaque to energetic quark and gluon probes. I will present an overview of the results establishing the creation and behavior of a hot ($T = 2 \times 10^{12}$ K) quark-gluon liquid at RHIC and its quenching of energetic probes. The quark-gluon liquid has behavior and properties similar to those of strongly-interacting classical fluids that are studied in atomic physics. Remarkably, a theoretical approach to black holes involving strings in five dimensions can describe the unique properties observed in this quark-gluon liquid.
The central dogma of molecular biology was formulated in the 1950s, soon after the discovery of DNA structure by Watson and Crick. It states that the information flow in the cell is from DNA (which stores the genetic information) to RNA (which acts as a “messenger”) to proteins (which carry out the bulk of cellular functions). DNA is copied to RNA in a process called transcription. The base sequence of RNA is then translated (using the genetic code as a “dictionary”) into the amino acid sequence of proteins. In this picture, still largely present in textbooks, RNA is the -somewhat boring- “middle man” between DNA and proteins.

This picture started to change in the early 1980s, when Tom Cech, Sidney Altman and others discovered that certain RNA molecules, much like proteins, can fold into distinct 3-dimensional shapes and catalyze chemical reactions, a discovery for which they shared the Nobel Prize in Chemistry in 1989. Even more recently, it has become increasingly clear that RNA molecules control transcription and translation through a variety of mechanisms and play a key role in regulating the metabolic state of the cell. Only 2% of the human genome codes for proteins, but as much as 50% is transcribed to RNA, a sizable fraction of which is presumably involved in gene regulation and other cellular functions in ways that we are only beginning to understand. It is in that sense that RNA can be called the “dark matter” of the genome. A number of researchers at Stanford are involved in RNA science, two of whom were awarded Nobel Prizes in 2006. Roger D. Kornberg received the Nobel Prize in chemistry for his contributions to the understanding of the intricate machinery that carries out transcription and Andrew Z. Fire (shared with Craig C. Mello of the University of Massachusetts) was awarded the Nobel Prize in Medicine for their discovery of “RNA interference,” one of the mechanisms by which RNA can regulate genes.

While traditionally in the realm of biochemistry and molecular biology, RNA science offers interesting questions to physicists. The RNA backbone is highly negatively charged and in order to fold into a distinct 3-dimensional shape, RNA must overcome an enormous Coulombic repulsion. Overcoming this free energy barrier is facilitated by the presence of positively charge counter ions, such as Mg2+. The resulting problem of computing the arrangement and interaction energies of negatively charged RNA surrounded by a cloud of mobile ions is a classical analogy to the quantum mechanical problem of computing the electron density around charged nuclei. The energy scale of the classical problem is set by kT, as opposed to h-bar in the quantum mechanical case.

We are currently working on expanding the traditional Poisson-Boltzmann mean-field approach to the problem.
Mysterious Neutrinos

By Stanley Wojcicki

Neutrinos are believed to be among the 12 fundamental constituents in our universe, but they are probably the least understood because their interaction with matter is so weak, and thus they are hard to study.

A little over a decade ago we began an experiment called the Main Injector Neutrino Oscillation Search (MINOS) with a goal to investigate in detail early hints of anomalous neutrino behavior from the atmospheric neutrino experiment in Japan, Kamiokande (and supporting evidence from the U.S. from the Soudan II experiment), using a well controlled accelerator produced beam of neutrinos. The neutrinos were to be produced by the 120 GeV Fermilab Main Injector proton accelerator and detected some 735 km away in a former iron mine in Soudan, MN.

To make the experiment a reality, we had to build a highly sophisticated proton and neutrino beam line at Fermilab, excavate a new cavern (more than half the size of a football field) in the Soudan mine (700 m underground) and build 2 large detectors, one at Fermilab and another in the Soudan cavern, the latter with a mass of about 5400 tons. And to make this happen, we had to create a new collaboration (currently about 150 scientists from 32 institutions in 6 countries — the United States, United Kingdom, France, Greece, Brazil, and Russia) and last, but far from least, obtain endorsements, approvals and, very importantly, funding from the relevant funding agencies. So it is not surprising that it took a decade to get it all accomplished and obtain first results.

The fact that neutrinos hardly interact allows us to send them 735 km through the earth without having to build a tunnel of that length. But it also creates a drawback — the number of neutrinos you have available for your study is small, even with a multi-kiloton detector. We observe roughly 1-2 accelerator produced neutrino interactions per day in the Soudan detector. To give those few interactions, about 10 billion neutrinos have to pass through the detector each day.

But all the barriers and challenges notwithstanding, MINOS and the associated infrastructure are now working, probably better than our most optimistic expectations. The first results on atmospheric neutrinos were published over a year ago. This past November the results from our first data obtained with the accelerator beam were published in Phys. Rev. Letters. Our results confirm the earlier indication that muon neutrinos do indeed “disappear” as they travel through space and that this disappearance is consistent with oscillations into tau neutrinos. We also obtained the most accurate to date measurement of mass squared difference between two neutrino mass states. The value for mass squared difference between two neutrino states is about \(2.7 \times 10^{-3}\) eV\(^2\). The absolute mass scale is still known only very poorly, but this indicates that the neutrino masses are in range between one ten millionth \((10^{-7})\) and one millionth \((10^{-6})\) of the mass of the electron, the lightest known particle so far.

The experiment will continue to take data for the next 3-5 years and we hope to increase the statistics by at least an order of magnitude. We hope to significantly improve the accuracy of neutrino parameters, investigate whether there is any contribution from neutrino decay, search for sterile neutrinos, and search for as yet unseen oscillation mode numu->nu_e which is known to be small but may hold the clues to the

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Supermassive black holes existed even when the universe was less than one billion years old, and they power some of the most luminous objects in the universe — quasars. But how do they form? Do small black holes, left behind by the earliest stars, feed continuously from the surrounding gases to grow in mass some 100 million fold? That is one theory — another possibility is that they form on rare occasions. When an unusually large amount of material is compressed in the center of a galaxy, it may collapse very rapidly. In fact, this can happen so fast that it does not have time to break up into smaller lumps and form stars. Instead, the gaseous cloud attempts to make a star many thousands of times the mass of our sun. The huge inward gravitational pull of this enormous mass cannot be countered by even the thermal pressure from nuclear fusion in the center of the cloud, and as a result, the mass collapses. In this complicated process, it could be that the cloud flattens into a disk and then breaks up into smaller pieces, or stars. Their explosions could push the rest of the gas out of the system, leaving just some regular stars and a few small black holes orbiting each other. It has been difficult to study any of these processes theoretically. One needs to follow regions thousands of light years across from where the gas contracts to scales much smaller than a star.

Physics graduate students John Wise and Matthew Turk made enormous progress in developing the numerical tools to study many of these processes in stunning detail. Their most recent calculation not only captures the formation of early galaxies, but also follows how parts of the galaxies collapse to scales smaller than a single star. Their technique is called adaptive mesh refinement, which behaves like a telescope that never loses resolution no matter how far one zooms in on a region of interest. They demonstrated this ability by capturing even regions one hundred trillion times smaller than the entire volume they considered! Wise and Turk carried out their simulation on KIPAC’s Silicon Graphics supercomputer using some 20,000 processor hours.

A small fraction of the entire cloud collapses very rapidly to high densities. At different scales, multiple nested disk- and bar-like structures form as their angular momentum becomes important. What was unexpected and unseen in any previous investigations is that these disks and bars all point in uncorrelated directions. In hindsight, this seems an obvious outcome for an initially turbulent cloud collapsing under its own gravity. It makes a big difference whether there is one isolated disk or multiply-nested ones, as the friction of one disk with its surrounding disk can preferentially slow fast-moving material and force it to collapse more rapidly than it would without that drag.

This calculation demonstrated that the new algorithms make it computationally feasible to start with realistic initial conditions and follow all relevant physics in order to study whether black holes can form from collapsing gas clouds in the very early universe. This increase in capability makes many other physical details more important. Turk and Wise are working hard to follow the formation of stars, feedback from their radiation, and the ensuing supernovae explosions. Nature may hold more surprises than computational cosmological models can capture today, but the virtual universes are more realistic than ever.
Apker Award Finalist 2006

We are pleased to report that INNA VISHIK, one of our outstanding Physics undergraduates (now a graduate student in Applied Physics) was selected as a finalist for the coveted Apker Award. The Apker Award recognizes outstanding achievements in physics by undergraduate students and provides encouragement to young students with great potential for future scientific accomplishments. Two awards are presented each year, one to a student from a Ph.D. granting institution and one to a non-Ph.D. granting institution. Inna was chosen as an Apker finalist for her outstanding undergraduate achievements in research (her work was also recognized by a Firestone Award last year). Congratulations, Inna!

Neutrinos – from page 4

matter antimatter asymmetry in our universe.

The Stanford group has played an important role in the experiment from the very beginning. I served as the spokesperson for the experiment for the first 8 years and then subsequently as a co-spokesperson, first with Doug Michael — a highly talented former Stanford undergraduate who passed away a little over a year ago — and more recently with Rob Plunkett from Fermilab. Other members of the Stanford group are senior research associate George Irwin, postdocs Hyejoo Kang and Simona Murgia and graduate student Tingjun Yang. Former postdocs Carlos Arroyo, Larry Wai and Sergei Avvakumov made crucial contributions in the earlier stages of the experiment.

2006 Student Awards

A number of student awards were announced at our Physics/Applied Physics Commencement ceremony last June. ARIEL SOMMER received the David Levine Award, presented to the outstanding Junior physics major. JENNIFER MEYER received the Jeffrey Willick Memorial Award, given to the outstanding physics student in the field of astronomy. The Paul Kirkpatrick Award, given to outstanding physics teaching assistants, was given to EREZ BERG and ERAN MUKAMEL. ASIMINA ARVANIKTAKI, AMIN MUSAFA and NAVIN Sivandan were all recipients of Centennial Teaching Awards.

The Firestone Award for excellence in Undergraduate Research was presented to INNA VISHIK, who was also a finalist for the prestigious Apker Award (see article this page). Congratulations to all of our outstanding Physics students!
We are pleased to report that the Physics Department received a generous gift from one of our former students in honor of Karl van Bibber, a former Stanford Physics Department colleague in experimental nuclear physics, now working at Lawrence Livermore National Laboratory. The Karl A. van Bibber Postdoctoral Fund in Physics will support postdoctoral scholars in the Department of Physics over the next five years. Postdoctoral scholars Peter Fierlinger, who works with Prof. Giorgio Gratta, and Judy Lau, who will be working with Prof. Sarah Church, were selected as the first recipients of this fellowship.

**Physics Alumni Reception**

Thanks very much to those of you who attended our Physics alumni reunion reception on October 13, 2006, as part of the Reunion Homecoming Weekend. The Physics department reception was attended by approximately 35 physics alumni, in addition to a number of Physics faculty, staff and current students. Department Chair Stan Wojcicki, along with Professors Patricia Burchat, Sarah Church, Giorgio Gratta, Peter Michelson and Bob Wagoner, were happy to chat with some of their former students and colleagues.

The celebratory event provided another opportunity for alumni, faculty, and staff to get together, and we were pleased to present our new Physics and Astrophysics building to the attendees. It was wonderful to catch up with former students and some of their young families. Please look for announcements of future alumni events on our website, and plan to attend!

**RNA** - from page 3

(which is analogous to Hartree-Fock theory in quantum mechanics) to account for the finite ion size and ion-ion correlations.

In a collaboration with Dan Herschlag in the medical school, we are using synchrotron radiation at the Advanced Photon Source and at the Stanford Synchrotron Radiation Laboratory to study the structure of RNA in solution. Our small-angle X-ray scattering measurements allowed us to explore the conformational “landscape” of a “riboswitch,” an RNA molecule that changes shape in response to binding a small-molecule ligand. In the cell, this conformational change controls the expression of a genes, “switching” them on or off in response to the cell’s environment. Our measurements provide a first glimpse into the molecular details of how this riboswitch achieves its function. For more information see [1].

pleased to have this talented young cosmologist join our faculty.

A search has been underway for one or two new junior experimental astrophysics faculty covering two areas; one in gamma ray astronomy and the other cosmology, with an emphasis on developing new or advanced instrumentation. Please consult our website (http://www.stanford.edu/dept/physics/jobs.html) for updates on this and other faculty searches.

Sadly, the physics community lost two distinguished colleagues and exceptional friends this past year. Walter Meyerhof and Melvin Schwartz, both of whom served on the Physics faculty for many years, each made important contributions to the physics community. Walter Meyerhof was Chair of the Physics Department from 1970 to 1977, and also served as department Ombudsperson. In addition to his excellence in research and teaching, Meyerhof encouraged minority and women students to study physics. Melvin Schwartz shared the Nobel Prize in Physics in 1988 “for the neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino.” They will both be deeply missed, but the legacy of their outstanding work will continue for years to come.

A number of our Physics faculty received prestigious awards in 2006. Associate Chair Patricia Burchat received a Gabilan Professorship, given to support an outstanding female faculty in the sciences. Prof. Burchat was chosen in recognition of her noteworthy research in experimental particle physics and her influence in understanding the differences in the way matter and antimatter evolve over time. Savas Dimopoulos and Steve Shenker were both elected as fellows of the American Academy of Arts and Sciences, one of the country’s oldest honorary learned societies. Shoucheng Zhang was elected a fellow of the American Physical Society for his pioneering contributions to the development and exploitation of the effective field theories of highly correlated electronic systems. David Goldhaber-Gordon received the Award for Initiatives in Research from the National Academy of Sciences, an award which recognizes innovative young scientists, and encourages research likely to lead toward new capabilities for human benefit.

I am also pleased to report that Sarah Church was promoted to Associate Professor with tenure this past year, and that Todd Hoeksema, a Senior Research Scientist in Professor Phil Scherrer’s Solar Physics group, received the NASA Distinguished Public Service Medal. This award resulted in Todd’s significant work on NASA’s heliospheric physics programs at both NASA and Stanford.

Our Physics students have also been recognized for their exceptional work with a number of awards (see article on page 6). A new class of 28 students entered our Ph.D. program in 2006. The incoming graduate students include three women and ten foreign students. We are very pleased to welcome these bright new students to our department.

We hope you will enjoy reading about some of the research going on in our department, and that you will consider attending the upcoming Robert Hofstadter Memorial lectures this spring (see article for details).

Thanks to those of you who were able to attend our Physics alumni reception last October — it is always a pleasure to meet with Physics alumni, and I encourage you to stop by the department for a visit whenever you are in the area. On behalf of the department, I thank you for your continued interest and support.

Best wishes,

Stanley Wojcicki
Chair and Professor of Physics