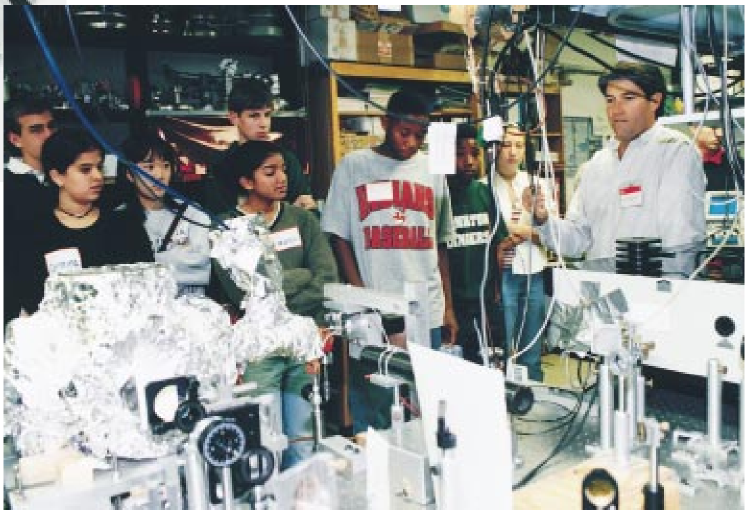
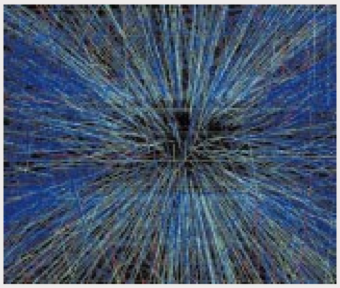
Physics Open House



Clockwise from upper right: William Saam participates in demonstrations. Linn Van Woerkom's laser lab always proves popular. Mary Bailey teaches physics students a little chemistry. Maarten Rutgers creates the world's largest soap bubbles. And (top left) students always enjoy learning physics through toy demonstrations with Xueli Zou.

Ohio State's Nuclear Experimental Group reports on atom smashing

Professors Tom Humanic, Mike Lisa, and Evan Sugarbaker are members of the STAR collaboration. On June 12, 2000, the operators in the main control room of the Relativistic Heavy Ion Collider (RHIC) announced that the STAR detector captured the first spectacular images of particles streaming from a head-on collision point. Beams circulate in the collider's twin rings on a collision course at an energy of 30 billion electron volts (GeV) per nucleon. Later, events indicated that PHOBOS also detected the collisions.

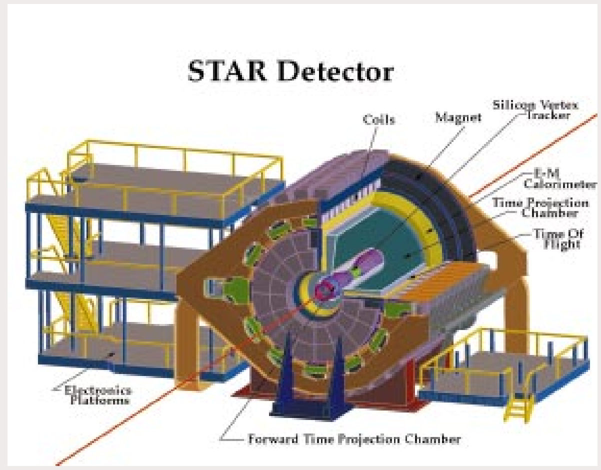


First images from the STAR detector.

The result is great news to the thousands of physicists, engineers, and support staff who have been working since 1991 to get RHIC up and running, and to physicists everywhere who have been anticipating RHIC's debut. These spectacular subatomic collisions are the culmination of many years of hard work, and they mark the beginning of a new era of discovery in nuclear physics. The kinds of high-energy collisions produced by this extraordinary machine should further enhance our understanding of the fundamental nature of matter.

For the full news release, see the web site of the American Institute of Physics at www.aip.org.releases/2000/rhic.html.

For more information and to follow RHIC's progress, go to www.rhic.bnl.gov/.

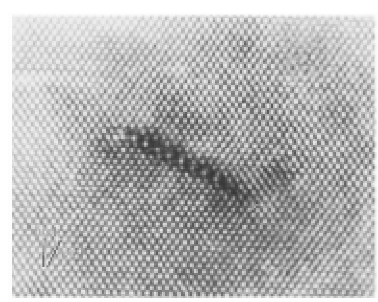


A computer-designed image of the detector.

The actual RHIC detector surrounded by about one-third of the international collaborators on the project.

Steering around the silicon road block: Professor John Wilkins

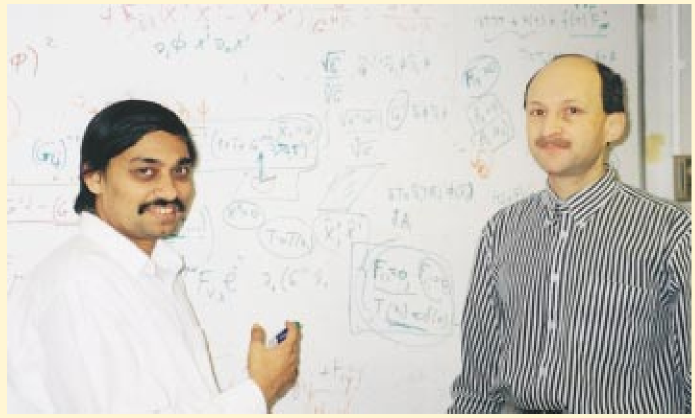
The "Silicon Roadmap"—an industry development plan to continue reducing transistor size—identifies basic problems to be solved. One involves the implanting of boron to produce increasingly finer features. In the subsequent annealing to restore the material's high conductivity, the boron diffuses 10-100 times further than expected, making features larger than desired, perhaps blocking the roadmap. The suspected culprit is the interstitial silicons that are kicked out of their lattice positions during the implanting. Electron microscope pictures show plate-like defects that might be the interstitials. Computer modeling finds that planes of interstitials are amazingly stable. This seems surprising since interstitials should disrupt the four-fold bonding that stabilizes materials such as silicon and diamond. The modeling reveals that interstitial chains can form planes with only four-fold bonds except at the ends of the chains—hence the planes cost little energy to form. Does this explain the enhanced diffusion of boron? Using parameters deduced from this work, others can study the diffusion of boron in the presence of the silicon interstitial planes. Perhaps a way around the roadblock can be found.



Transition electron microscope picture of the extended silicon interstitials.

String Theory at Ohio State

By Fernand Hayot



Samir Mathur, left, and Arkady Tseytlin

The popular scientific press has dubbed string theory the so-called "theory of everything." "Everything" is a lot. What researchers seek is a theory that would encompass both quantum mechanics and gravitation, thus unifying two great developments of the 20th century, Einstein's classical theory of general relativity and the quantum mechanics of Bohr and Schroedinger.

Since autumn of 1999, the Department of Physics has built a string theory group starting with two senior people: Arkady Tseytlin, born in Moscow, and Samir Mathur, born in Allahabad. Tseytlin holds a Ph.D. and D.Sc. from the Lebedev Institute in Moscow and was a reader in Theoretical Physics at Imperial College in London before joining the Ohio State physics department as a professor. Mathur has a Ph.D. from the University of Bombay and was an associate professor at M.I.T. before coming to Ohio State as an associate professor. Mathur and his collaborator S. Das did the "near extremal" black hole calculation, which sheds light on the black hole information paradox.

The story of black holes is fascinating. We know that an object too close to a black hole is swallowed, pulled in by the enormous gravitational force. Is the information the object carries irretrievably lost or can it be reconstructed from the radiation, the so-called Hawking radiation, which a black hole emits as it evaporates? This is the black hole information paradox. This paradox suggests that in any theory that incorporates general relativity there must be a breakdown of usual quantum mechanics.

Because we know of the existence of black holes in our galaxy and others, black holes have become the theoretical laboratories of string theory. If quantum mechanics holds for a black hole, information can be retrieved because of the reversibility of quantum mechanics. If not, quantum mechanics fails at distances where gravitation becomes infinitely strong. This would be strong medicine.

The public's fascination with string theory was evident last summer with the large turnout at Brian Greene's public lecture about string theory (see page 6 for details).

Professor Tseytlin's notes that "the development of string theory underwent rapid progress during the last six years with the introduction of new extended states called 'D-branes,' which are membrane-like excitations in higher dimensions, and also because of the unifying role played by the 11-dimensional formulation called M-theory. D-branes represent a special class of black holes in string theory and provide a theoretical laboratory to study quantum properties of black holes using string-theory or gauge-theory methods."

An impressive set of ideas is rapidly emerging that suggests how properties of ordinary quantum field theories, particularly Yang-Mills gauge theory, are linked to string theory. There is now growing hope for understanding how field theories may be described non-perturbatively. This may have very intriguing repercussions for a wide range of applications in particle physics.

Tseytlin's work was at the center of these new advances. His main areas of research include: black holes and extended brane solutions in string theory and M-theory; relations between gauge theory and gravity descriptions of D-branes of superstring theory; and string theories in curved backgrounds and their gauge-theory connections.

Professor Mathur notes that string theory has so far provided remarkable evidence that the black hole information paradox can be bypassed and general relativity and string theory can be made consistent with each other. But the physical mechanism for bypassing the paradox is not understood in any explicit way.

"There must be a clear mathematical formulation of the theory that makes its symmetries manifest, but we have not yet found the right variables for such a description," said Mathur. "It is likely that new mathematical tools will be needed to obtain such a description. In addition, strings must make contact with the physics of the low energy world that we observe around us."

In addition to their research, Professors Tseytlin and Mathur are also developing graduate level courses in string theory.

"I am very pleasantly surprised by the interest among the students and faculty in courses related to string theory," said Mathur. "The material is fast developing, and thus not available in books for the most part. It has been an interesting project to develop courses that are accessible to every graduate student and explore the current work in the field. So far, I have taught a course in general relativity showing its links to string theory, and another course explaining the details of the black hole information paradox."

Professor Tseytlin taught a supersymmetry course spring quarter and plans to teach string theory in the near future.

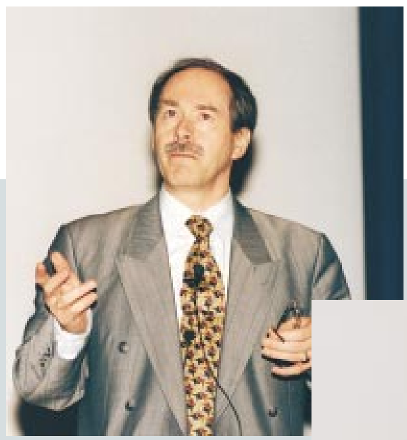
1999 Nobel Laureate gives 38th Annual Smith Lecture

The Alpheus Smith lecture for the year 2000 was given on May 1 by Gerardus 't Hooft, the fourth consecutive year that the lecture has been given by a new Nobel laureate. The 1999 Nobel Prize in Physics was awarded by the Royal Swedish Academy of Sciences jointly to Gerardus 't Hooft and Martinus J.G. Veltman. The Academy's citation was "for elucidating the quantum structure of electroweak interactions in physics." In his visit to Ohio State, 't Hooft displayed humor, brilliance, and a genuine affection for sharing his knowledge. An impression of his warm sense of humor can be obtained from a view of his web site at www.phys.uu.nl/~thooft/.

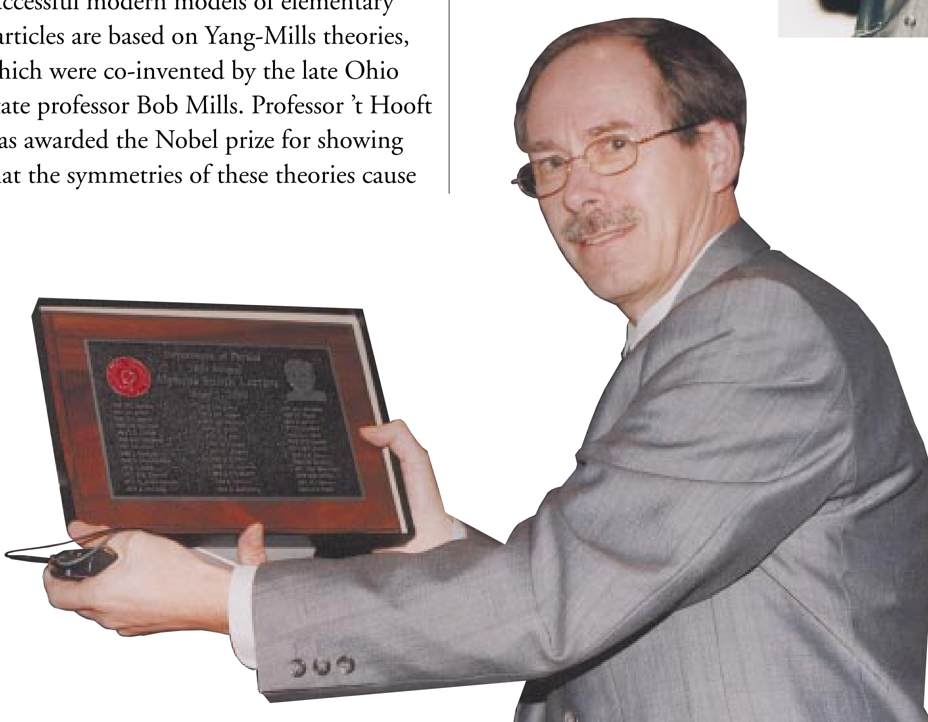
In his Smith lecture entitled "A Confrontation with Infinity," 't Hooft described the early attempts at constructing realistic models for the elementary particles. Most of these models resulted in infinite and therefore meaningless expressions. Even something as basic as the mass of the electron appeared infinite. The extremely successful modern models of elementary particles are based on Yang-Mills theories, which were co-invented by the late Ohio State professor Bob Mills. Professor 't Hooft was awarded the Nobel prize for showing that the symmetries of these theories cause the infinities to cancel. While the cancellations may appear to be due to "mathematical sorcery," 't Hooft explained in his lecture that they are actually based on physical insights. Professor 't Hooft met the challenge of describing this phenomenon to a lay audience with seeming ease. The wide variety of audience members at the well-attended lecture demonstrated a broad interest in the subject.

Gerardus 't Hooft is also well-known for a long standing debate with Stephen Hawking over one of the deepest problems in theoretical physics: the conflict between quantum mechanics and Einsteins's theory of gravity. The debate between Hawking and 't Hooft is described in an entertaining article by Leonard Susskind that appeared in *Scientific American* in April 1997. Hawking argued that information must be lost in the evolution of black holes, which would violate one of the basic principles of quantum mechanics. Not so, said 't Hooft. Black holes must abide by the laws of quantum mechanics, and it must be our understanding of gravity that is incomplete. Recent results in superstring theory have strongly tipped the balance of scientific opinion in favor of 't Hooft.

In addition to the Smith Lecture, 't Hooft met with graduate students and also with colleagues to discuss black holes and quantum mechanics. In a special seminar, he described a new theory, "The Holographic Principle," that is emerging from his studies of the quantum mechanics of black holes. He believes that quantum mechanics itself must ultimately be replaced by a completely deterministic theory. According to 't Hooft, nature is a big jigsaw puzzle, and he sees his task as trying to fit pieces of it together. You can read more about that in his book *In Search of the Ultimate Building Blocks* from Cambridge University Press.



't Hooft enthralled the audience during the Smith Lecture.



The Department of Physics presented 't Hooft with a replica of the Smith Lecture plaque.

Robert Laurence Mills

The Department of Physics expresses condolences to the family of Robert Laurence Mills, Professor Emeritus in the department, upon his death in October 1999.

Professor Mills received his A.B. from Columbia University in 1948, a B.A. and an M.A. from Cambridge University in 1950 and 1954 respectively, and his Ph.D. in physics from Columbia University in 1955. He was a research associate at the Brookhaven National Laboratory from 1953 to 1955, and a member of the Institute of Advanced Study in 1955-56. In 1956 he joined the Department of Physics at Ohio State as an assistant professor, and rose to professor in 1962. He served as vice chair for Undergraduate Studies from 1992 until his retirement in 1995. Following his retirement he lectured as a Fulbright Scholar at St. Patrick's College near Dublin, Ireland.

His research and that of his graduate students was in quantum field theory, many-body theory, and the theory of alloys. He was the author of two books: *Propagators for Many-particle Systems: an Elementary Treatment* (Gordon and Breach 1969) and *Space, Time, and Quanta: an Introduction to Contemporary Physics* (W.H. Freeman 1994).

Professor Mills shared the Rumford Premium of the American Academy of Arts and Sciences with C.N. Yang. This award honored the seminal work on the gauge field theories now known as Yang-Mills theories, which to quote *The Scientist,* have emerged as "the foundation for current understanding of how subatomic particles interact, a contribution which has restructured modern physics and mathematics."

He and his wife, Lee, were very active in community affairs, and in 1991 they shared the International Community Service Award of The Ohio State University Office of International Affairs. He also received the Rosalene Sedgewick Faculty Service Award for outstanding service to undergraduates in the College of Arts and Sciences.

Professor Mills was a member of the American Physical Society, the American Physical Society Forum on Physics and Society, the American Association of University Professors, and the Federation of American Scientists. His broad interests and activities were well characterized by C.N. Yang, who said, "Bob had a brilliant mind. He was very quick at grasping new ideas."

A gentleman of unfailing good humor and sincere and active concern for helping others, Robert Mills will be long remembered with great respect and affection.

K. Narahari Rao

The Department of Physics extends condolences to the family of K. Narahari Rao, Professor Emeritus of the department, upon his death in May 2000.

Professor Rao received his Ph.D. from the University of Chicago in 1949 under the direction of Dr. Gerhard Herzberg (Nobel laureate, 1971). He was at the National Physical Laboratory in Delhi, India from 1950 to 1952, then Duke University and the University of Tennessee from 1952 to 1954. He came to the Department of Physics at Ohio State in 1960 as a research associate, became associate professor in 1960, and was promoted to professor in 1963. In 1992 he retired as Professor Emeritus of Physics.

His research was centered in the field of high resolution infrared spectroscopy. Throughout his career, he addressed a need for better wavelength standards in this region, which culminated in the publication with Dr. Guy Guelachvili of the *Handbook of Infrared Standards* (Academic Press 1986 and later editions). He also led in the development of improved methods of studying infrared spectra at higher and higher resolution. These methods were applied to the determination of molecular constants, studies of intra-molecule interactions, and observations of transitions normally considered to be unavailable for study.

These research activities resulted in over 300 publications, including six books and six major review articles. He worked with 43 students who received Ph.D. degrees, 36 students who received M.S. degrees (with thesis), 10 postdoctoral fellows, and 34 visiting scientists from nine countries, many of whom returned on several occasions.

Professor Rao was involved in the development of the *Journal of Molecular Spectroscopy* from its inception in 1957, when he served as assistant editor to Harald H. Nielsen. In 1973, he became editor of the journal. When he stepped down in 1995, the journal had increased in size by a factor of six, and he had processed nearly 10,000 articles essentially singlehandedly.

During the same period he also played a similar role as director and organizer of the international "Symposia on Molecular Structure and Spectroscopy." These conferences are held annually at Ohio State and are attended by 400-500 scientists from around the world. His role with the journal and the symposium led to a special recognition in 1992 at his retirement, as well as the creation of the annual "Rao Prizes" given to three young scientists for outstanding first presentations at the symposium.

Professor Rao was elected to the Cosmos Club in 1967, received the Asian Indians in North America Prize for Basic Research in 1980, the Indian National Science Academy Endowment Lecture in Spectroscopy in 1982, the Marcus Marci Medal of the Czechoslovak Spectroscopy Society in 1985, The Ohio State University Distinguished Scholar Award in 1986, the Faculty Service Award from the National University Continuing Education Association in 1987, the Pittsburgh Spectroscopy Award in 1988, The Ohio State University International Outstanding Faculty Award in 1992, and the William Fowler Award from the Ohio Section of the American Physical Society in 1993. He is also a fellow in the American Physical Society and the Optical Society of America.