Chapter 18 New People, New Physics

This book's subtitle implies that we will cut off the narrative at 1990. But I'm sure you would like to know something about the physics research done at CWRU this past decade and a half. In fact, in several earlier chapters, I have described some of the more recent exciting work done by my colleagues. For example, I explained how Bob Brown has exploited his expertise in electromagnetism and quantum mechanics to become a world player in medical imaging; and how Dave Farrell has advanced from basic research on superconductivity to medical applications of biomagnetism; and how Arnie Dahm has capitalized on his skill in manipulating individual electrons to take a first step into the world of quantum computing.

If you were to visit the department in 2005, you would find twelve (about half) of its faculty, along with a dozen research associates and about two dozen graduate students conducting exciting, world-class programs in three research areas:

- optical materials and nanotechnology,
- particle/astrophysics/cosmology theory,
- astrophysics and cosmology experiment.

In this chapter, I present brief descriptions of the research interests of these twelve physicists and their groups.

Optical materials: light on matter

Rosenblatt	**Singer**	**Kash**	**Shan**
1987	1990	1994	2002

Charles Rosenblatt (PhD Harvard 1978) arrived in 1987 to establish a program in liquid crystal research. **Kenneth Singer** (PhD Pennsylvania 1981) came three years later to begin a new program in optical materials. **Kathy Kash** (PhD MIT 1982) was the first new member of the faculty after the arrival of Lawrence Krauss as chairman. More significantly, she was the first woman full-time faculty member in the 165 year history of the department. In 1994, Kash set up a laboratory for research in mesoscopic systems. The next addition to the department is its second woman physicist, **Jie Shan** (PhD Columbia 2001), who works in ultra-fast spectroscopy. This group of four experimentalists, working in related frontline areas of applied physics, is complemented by the four condensed matter theorists: Phil Taylor, Rolf Petschek, Walter Lambrecht, and Harsh Mathur.

Rosenblatt – liquid crystals

In Chapter 12, we described some of the experimental work done by Gordon and Schuele on the properties of liquid crystals (LC's). Then, in Chapter 17, we mentioned Petschek's theoretical investigation of ferroelectric LC's. Chuck Rosenblatt's group, which currently includes one post-doc and four grad students, has established a significant liquid crystal research program. The first among several topics they are investigating is the study of phase transitions from one liquid crystalline state to another. An example is the transition between the nematic (molecules aligned in a preferential direction) and the isotropic (random alignment). A second area if interest is the study of LC's which have ferroelectric behavior. A third topic concerns the interface of the LC and its "container". Since liquid crystals are usually confined between two flat surfaces, their interaction with the substrate plays an important role in their behavior. Rosenblatt and his group have explored the possibility of influencing the way in which the molecules align themselves at the interface. They have, for example, investigated coating the substrate with a polymer layer, and then to mechanically score alignment grooves in the polymer with the stylus of an atomic force microscope. From the group website: "… we scribe patterns onto a polymer-coated substrate as small as 10 nanometers in length, approximately one ten-thousandth the width of a human hair. The liquid crystal molecules are forced to align parallel to the scribing direction, allowing us to study phase transitions and elastic behavior on very tiny length scales."

Fig. 18-1.
Chuck Rosenblatt.

The ultimate goal of these studies is to develop LC's which are fast, stable, cheap and applicable in many areas of optics, including such things as the control of optical signals in communications and computer technology.

Singer – nonlinear optics

Ken Singer and his group (currently 5 grad students and one post-doc) are interested in "non-linear optics". Ordinarily, when light passes through matter, like a glass lens, it gets partly absorbed and is slowed down by interactions with the electrons in the medium. The frequency of the light remains unchanged. This is *linear* optics. If the light is very intense (as light from a laser), its electric fields push the electrons around, resulting in an oscillating polarization of the medium. The oscillating electrons produce their own radiation. In this case, the transmitted beam can have small components with twice, thrice, or other multiples of the frequency of the incident beam. This is called "harmonic generation." (A hundred years earlier, Dayton Miller was studying sonic harmonics generated in musical flutes.) There are other interesting and potentially useful nonlinear effects, such as dependence of the speed of transmission on the frequency, or the shifting of the phase of the light beam. The optical materials which behave in this way usually consist of organic molecules which can be linked together to form polymers. The polymers in turn spontaneously organize themselves into crystals and liquid crystals, sometimes in a single molecular layer.

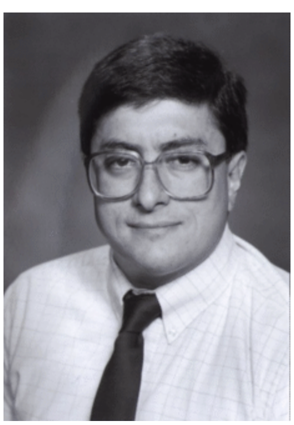

Fig. 18-2.
Ken Singer.

From the group website: "Members of our research group measure optical, electronic, and structural properties of organic electronic and photonic materials with the aim of gaining an understanding of the physical origin of optical and electronic properties, as well as the potential of particular materials for optoelectronic devices." "We also study how these materials might be used in devices, such as solar cells, displays, optical switches, image processors, and other electronic and optical devices."

Kash – reduced dimensionality, crystal growth

Kathy Kash is doing research in nanotechnology, specifically in the preparation of semiconductor devices for the study of linear and nonlinear optical processes. In a "semiconductor quantum well", electrons and holes are restricted to move in planes between alternating layers of low-band-gap and higher-band-gap semiconductors. When particles are constrained to very small regions of space, in this case to a two-dimensional sheet, their motions are determined by quantum mechanics. Kash has studied the quantum confinement of excitons, i.e. electron-hole pairs created by a laser. Excitons can be further restricted to one-dimensional "quantum wires" or even to "quantum dots". From the group's website: "The goal of the effort is to study linear and nonlinear optical processes as they are modified by quantum confinement, and to study phase transitions of collections of particles in these systems of reduced dimensionality."

Fig. 18-3.
Kathy Kash.

Most recently, Kash has been collaborating with colleagues in Chemical Engineering and Macromolecular Science. One such project involves the growth of large single crystals of gallium nitride at near-atmospheric pressure. Currently, this can be done only at extremely high pressures, and success of the new approach being investigated by Kash and her colleagues would have a very important impact on industrial applications.

A second research area concerns the electrochemical deposition of semiconductors. As Kash describes it, the aim is to "make devices 'in a bottle', very cheaply, and using schemes that could be made environmentally friendly". This work can involve nanometer sized "molecular templates" as patterns for very small wires and dots, whose remarkable quantum properties can be exploited. Currently, three grad students and one post-doc are working under the direction of Professor Kash.

Jie Shan – femtosecond pulses

Jie Shan is the fourth in this group of experimentalists who are studying the interaction of light with matter on the microscopic scale. Jie's specialty is "time domain spectroscopy" in which ultrashort electrical pulses are generated using femtosecond optical pulses to study charge transport properties of materials. The new radiation has frequencies in the terahertz or far-infrared region, with typical wavelengths a few hundred micrometers and photon energies a few milli-electronvolts. A 100 femtosecond pulse is typically only tens of micrometers long as it flies through the sample. Photons in this meV range match the energies of many fundamental excitations in solids and molecules, including phonons, low-frequency vibrational modes, rotations, and certain collective electronic excitations. One can use these pulses to investigate electrical charge transport in insulators and in nano-scale structures, such as the ones studied by Kathy Kash.

From Jie's website: "Currently we are focusing primarily on applications of ultrafast spectroscopy …. to the study of various condensed-phase systems including conventional materials and strongly correlated systems. Although both equilibrium and nonequilibrium properties are investigated, we emphasize pump/probe techniques to examine the dynamical properties of materials, such as carrier and spin dynamics and energy relaxation. At present, we are particularly interested in probing the effects of reduced dimensionality associated with interfaces and nanostructures."

Fig. 18-4.
Jie Shan.

Essential to the research of each of these four condensed matter experimental groups is the department's **"nanoscale facility"** which is equipped with state-of-the-art instruments, such as an atomic force microscope and a near-field scanning optical microscope. The four faculty members are aided by a total of fifteen graduate students and three post-docs. Each group uses specially tailored light pulses to elucidate the quantum behavior of technologically interesting systems and materials: Rosenblatt studies mono-layers of innovative liquid crystals; Singer uses laser pulses to produce nonlinear effects in optical materials; Kash looks at the propagation of electron-hole pairs in two-dimensional quantum wells; and Shan uses extremely short bursts of radiation to examine dynamical properties of materials. Each group does "basic physics" research, using the newest techniques, to find out how materials behave under unusual or extreme conditions. Much of what they learn will reappear as "applied physics" as new technologies are perfected.

Particle/astrophysics/cosmology theory

C. Taylor	**Krauss**	**Starkman**	**Vachaspati**
1988	1993	1995	1996

Cyrus Taylor - factotum

Cyrus C. Taylor joined the department in 1988. He had completed his PhD at MIT in 1984, where he worked on field theory. He was the first particle theorist to be hired at CWRU since Bob Brown's arrival 18 years earlier. Taylor began his research at CWRU, working with graduate student Evalyn Gates, on a study of the quantization of phase spaces associated with various field theories. Later, he joined Bob Brown and research associate Shlomo Shvartsman in the development of the theoretical treatment of the quantum electrodynamics of heavy fermions. As we saw in Chapter 13, Brown and Shvartsman soon afterward moved from particle theory to medical imaging. At the same time, Taylor, too, made a significant move away from theory, being reincarnated as a particle experimentalist.

In 1993 Cyrus joined J. D. Bjorken of the Stanford Linear Accelerator Center (SLAC) in proposing an experiment to be run at the Fermilab Tevatron. The experiment, called MiniMax, was originally conceived as preliminary to a more complex run at the super-conducting super collider (SSC) in Texas. Following the defunding and demise of the SSC, the group, along with new collaborators, has submitted a proposal to undertake a similar experiment (christened FELIX) at the large hadron collider (LHC) currently being built at CERN in Switzerland.

Fig. 18-5
Cyrus Taylor

The MiniMax run at Fermilab took place in 1996 and the results were soon published in a Physical Review paper with authors from seven institutions. Included among the collaborators were three CWRU undergrads, two grad students, and professors Tom Jenkins and, a second converted theorist, Ken Kowalski. The experimental setup consisted of a large array of detectors placed alongside the intersection of the colliding protons and antiprotons. The total energy of the collisions was 1.8 TeV. Charged mesons and photons produced at very small angles relative to the beamline were detected. The goal was to determine the ratio of the number of neutral pions (which decay to two gammas) to the number of charged pions produced in the very high energy collisions. The tiny region in which the proton and antiproton annihilate into a burst of mesons has an extraordinarily high energy density, higher than anything short of a supernova. The theoretical motivation for the measurement was the proposal that, in such a situation, the symmetry of the charged and neutral mesons might be different from that observed in less frantic neighborhoods. The theorists' name for such behavior is "disordered chiral condensate". (Cyrus had, in fact, worked on the theory of chiral condensates as early as his grad school days at MIT.) Earlier experimental clues for DCC had been seen in atypical cosmic ray events. MiniMax produced several events which suggested a signal for DCC, certainly enough to support plans to continue the search in Geneva.

Theorist and experimentalist Taylor put on a third hat as inaugurator and director of the department's Physics Entrepreneurship Program (PEP). This is a 2-year master's degree program which, as described on its website, "provides studies in technology innovation and state-of-the-art physics, practical business instruction, and real-world entrepreneurial experience to individuals with a bachelors, masters, or PhD in a physics-related field". This program, which in its first four years has won several national awards, has been imitated in several other Case departments. In the summer of 2005, Cyrus Taylor succeeded Lawrence Krauss as chairman of the physics department.

Krauss – astrophysicist, communicator

Lawrence Maxwell Krauss joined the department as its new chairman in 1993. He had completed his PhD at MIT in 1982 where he worked on theoretical gravitation and big-bang physics. During the following three years at Harvard and six on the faculty at Yale, Krauss wrote prolifically on topics at the intersection of particle physics and cosmology. Several of his papers, including a few with his sidekick (now Nobelist) Frank Wilczek, described ways to detect and identify various dark matter candidates, papers of great value to the several groups who were building detectors to do just that.

In 1992, a distinguished external visiting committee was invited by the Dean of Arts and Sciences to evaluate the department and its potential They strongly recommended that, on Bill Gordon's retirement, a new chairperson should be sought from outside the university. Krauss, who was at the time on the Yale physics faculty, was already recognized as a leader in particle/cosmology theory and as the author of widely read popular books on modern physics. With the impending retirement of about half of the CWRU physics faculty, Krauss recognized the opportunity to build a new and competitive department. Central to his plan was to establish a nationally significant astrophysics effort. Consequently, during the following decade, two additional astro/cosmology theorists and four young astrophysics experimenters were recruited to the department.

At CWRU, Krauss has worked with research associates, Peter Kernan, Mark Trodden and Craig Copi, and with grad student Hong Liu, in studies of the formation of nuclei in the big bang, of the strange quantum properties of black holes, and of the weakly interacting massive particles (WIMP's) which have been proposed to account for the missing mass in the universe. This theoretical work, some of which directly addressed observational techniques, has been especially appropriate given the presence in the department of the four experimental groups to be described later in this chapter.

Fig. 18-6
Lawrence Krauss.

In 1995 Krauss and Michael Turner of the University of Chicago wrote a prescient paper on the "return of the cosmological constant", an idea which dominates current cosmology. This refers to the repulsive force originally proposed and then rejected by Einstein in an attempt to keep the universe from collapsing. More recently new data from observations of very distant supernovae indicate that the rate of expansion of the universe is actually increasing and the "cosmological constant" is at the center of the expanding universe discussion.

Krauss has been instrumental in the creation of CERCA, the Center for Education and Research in Cosmology and Astrophysics. With the support of the Kavli Foundation, the eight faculty members described in this chapter, along with members of the CWRU department of astronomy and colleagues at the Cleveland Museum of Natural History, have formed this center to provide "an interdisciplinary framework for interactions between faculty, postdoctoral researchers, graduate and undergraduate students, educators and the public. CERCA is particularly active in supporting the world class research activities of scientists at CWRU and making new connections to bring the excitement of this research to the public at many levels." (from the CERCA website)

Taking science to the public has always been a major component of Krauss' interests. While, at the same time chairing the department, producing significant research, and lecturing at all levels to audiences the world over, he has authored seven widely read books published in many languages. Krauss is known internationally as a champion of scientific integrity, speaking out against the abuse, misuse, and misunderstanding of science.

Starkman and Vachaspati – the particle-cosmology link

Within a year after Krauss' arrival, two young and well-published "particle-astrophysics-cosmology" theorists joined the department: Glenn Starkman and Tanmay Vachaspati.

After completing his BS at Toronto and his doctorate at Stanford, **Starkman** held post-doctoral positions at Princeton and Toronto. His work during these years concerned Big Bang nucleosynthesis, the role of neutrinos in the early universe and various candidates for dark matter. At Case, working with a string of post-docs, Glenn has studied topics concerning the early universe and how it got to where it is. One paper, "Does Chaotic Mixing Facilitate Ω<1 Inflation?", takes the prize for the most succinct abstract: "Yes, if the Universe has compact topology."

Fig. 18-7
Tanmay Vachaspati.

Vachaspati earned his doctorate in 1985 at Tufts, working with Alexander Vilenkin on the role of cosmic strings in the early universe. During the following decade, Tanmay divided his time among positions at the University of Delaware, Cambridge University, and Tufts. Vachaspati is especially interested in "cosmological defects". Consider that if the early universe, just after the big bang, were absolutely homogeneous, it would still be so. Some local variations, or defects, had to be there from the start in order to result in the universe we see today. Tanmay has looked at the potential role of such candidates as magnetic monopoles, cosmic strings and domain walls as responsible for the observed structure. At the opposite extreme, he is studying the impact of these "cosmic defects" on the properties of fundamental particles, for example in a paper titled: "An Attempt to Construct the Standard Model with Monopoles," Glenn and Tanmay have collaborated on a variety of projects, including a paper on galactic cosmic strings as sources of primary antiprotons. In 1999, they joined the mounting excitement in speculations about the accelerating universe in a paper with Mark Trodden on “the fate of the universe”. Tanmay took this a bit further in work with former grad student, Levon Pogosian, in speculations about the “dark energy” which seems to be responsible for the cosmological constant. They look at the observed large scale structure in the universe and the results of cosmic microwave background (CMB) surveys and deduce a picture in which we (along with all our brethren in our particular universe) find ourselves at a fork in the road, a coin-toss perhaps, pulling us possibly back into a big crunch.

Starkman, along with post-docs Copi, Trodden, Dejan Stojkovic, and Dragan Huterer, has pursued the nature of dark matter and the universe’s acceleration in a variety of ways, looking, for example, at the possible role of large extra dimensions or of possibly observable effects on gravitons. The abstract of a recent paper summarizes the state of the art in a colorful way: “The nature of the fuel that drives today's cosmic acceleration is an open and tantalizing mystery. We entertain the suggestion that the acceleration is not the manifestation of yet another new ingredient in the cosmic gas tank, but rather a signal of our first real lack of understanding of gravitational physics.”

Two other topics on Starkman’s list concern the search for circles in the sky and the observation that some of the cosmic structure in the CMB may not be cosmic after all. The first was a search for identical patterns of microwave structure on opposite sides of the sky. These might be expected if the universe has a topology such that there exists more than one route which the radiation can take to reach us from distant sources. No such matched patterns were observed, thus ruling out the “possibility that we live in a universe with topology scale smaller than 24 Gigaparsecs.” Room enough, I suppose.

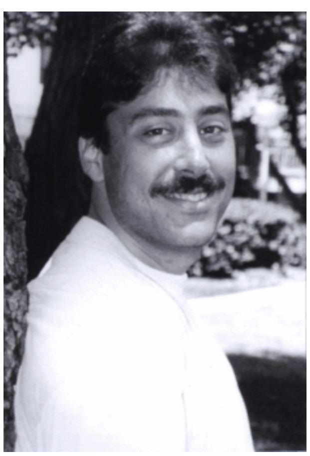

Fig. 18-8
Glenn Starkman.

The second topic is also related to the CMB data. The usual way to summarize the observed structure in the CMB is to plot the “power spectrum”. This is a measure of the temperature correlations between all pairs of points on the microwave sky as a function of the angular separation between them. Much of the current discussion on what happened after the big bang is based on the series of bumps which appear in the power spectrum – where preferred angular separations are evident. Starkman and company looked closely at these bumps and determined that the “large angle correlations” were different on opposite sides of the ecliptic plane (the plane in which the planets move around the sun). Why should cosmic processes bother about our modest little solar system? Michelson and Morley, and the persistent Miller, sought an effect of the motion around the sun, Starkman and company’s lopsided patterns in the large-angle correlations in the CMB seem to signal one.

Experimental Astrophysics and Cosmology

Akerib Covault Ruhl Shutt
1996 2001 2002 2005

Complementing the *theoretical* astrophysics/cosmology program is an exciting multifaceted research program pursued by a quartet of young experimenters, **Dan Akerib** (PhD 1991 Princeton), **Corbin Covault** (PhD 1991 Harvard), **John Ruhl** (PhD 1993 Princeton), and **Tom Shutt** (PhD 1993 UC Berkeley). These fellows and their groups are participants in a wide range of multi-national astrophysics collaborations, each one a search for particles or radiations from space, each one using different state-of-the-art detection systems. Their research may be described as a continuation of the pioneering neutrino work done in the 1960's by Crouch and Reines, and the cosmic ray work done in the 1970's by Frye and Jenkins, as described in Chapter 8.

Akerib - wimps

Fig. 18-9
Dan Akerib.

Daniel Akerib joined the department in 1996. He and his group of post-docs and grad students are part of the "Cryogenic Dark Matter Search" (CDMS) collaboration. The collaboration currently includes physicists from twelve institutions. Observations made during the past two decades indicate that the protons, neutrons and electrons which make up the stars, planets and sundry dust in the universe account for only a fraction of its mass. Better than 90% of the mass is unaccounted for. Whatever the missing mass is, it must interact very weakly with ordinary matter and is therefore very difficult to observe. Neutrinos, even though they are plentiful, have been ruled out as candidates for the missing mass. One possibility is that there exists a sea of "weakly interacting massive particles" (WIMPs) which are responsible for the observed gravitational effects and which have cooled down to non-relativistic energies. The CDMS and other experimental collaborations have developed instruments sensitive enough to detect the rare and tiny signals produced when WIMPs interact with nuclei.

As Dan explains on the department website: "The goal of my research is to try and detect WIMPs directly, through their elastic scattering from atomic nuclei in a terrestrial detector. If they were in fact produced in the early universe, WIMPs would have coalesced to form the dark matter halo of our Galaxy at detectable level. The experimental challenge is formidable. Because WIMPs are slow and weakly interacting, they lead to small energy transfers and very low rates."

Because the counting rates are so low, the detectors are placed in a deep mine to reduce the background from cosmic rays. Recall that Reines, almost forty years ago, reduced the cosmic ray background in his neutrino work by setting up in a deep gold mine in South Africa (Chapter 8). The Akerib group is responsible for the development of solid-state detectors which operate at temperatures of milli-Kelvins and which can detect both the burst of charge and the tiny rise in temperature caused by a WIMP hitting a nucleus. Because most of the residual background is from electrons or photons, the team has developed a detector which can pick out the rare WIMP signals. The ratio of the amount of ionization to the amount of heat for WIMP's is expected to differ from that for the background events.

The most recent run of the Cold Dark Matter Search, at the 2000 foot deep Soudan iron mine in Minnesota in the summer of 2004, has set a new upper limit on WIMP interactions. The germanium and silicon detectors (two kilograms total) were operated at 50 millikelvin. Assuming a WIMP flux consistent with their observed galactic gravitational effects, the group has been able to set an upper limit on the cross section for WIMP interactions with matter. This limit is significantly lower than that set by any other search – and, as the authors state: the result "constrains predictions of supersymmetric models". In other words, the non-observation of a signal at this level is starting to make the theorists scratch their heads.

Covault – cosmic gammas

Corbin Covault came to CWRU in 2001 after several years on the faculty of the University of Chicago. He has set up a group interested in the detection of ultra-high energy radiation and cosmic ray particles. One of the group's collaborations, STACEE (Solar Tower Atmospheric Čerenkov Effect Experiment), involves the search for extremely high energy bursts of gamma rays. A large array of mirrors (totaling 7000 square meters), spread out in the desert of New Mexico, catches the Čerenkov radiation produced at night by secondary particles moving through the atmosphere. These particles are produced in collisions in the atmosphere of incoming gamma rays in the 50 to 250 GeV energy range.

Fig. 18-10
Corbin Covault

From the STACEE website: "It is believed that observations of sources" in this range "will provide important evidence concerning the acceleration mechanisms of the most energetic objects in the Universe, including rotating neutron stars (pulsars), remnants of exploded stars (supernovae), gamma-ray bursts, and distant, but intense, active galactic nuclei (quasars)."

A second collaborative project, the Pierre Auger Observatory, involves the use of 1600 sets of Čerenkov and atmospheric fluorescence detectors spread over a 3000 km^2 area in southern Argentina. The goal is to detect electron showers produced by incoming cosmic rays at the highest-so-far end of the energy scale, say up to 10^{20} eV. The relative arrival times of the numerous secondary particles at each of the wide-spread detectors allow one to determine the direction of the incoming primary. The CWRU team has been responsible for the design and testing of the global positioning system (GPS) based components which are the key to the directional sensitivity of this exciting, multinational project.

Ruhl - CMB

John Ruhl arrived in 2002 to establish the third new experimental astrophysics group, this one a team in search of fine structure in the cosmic microwave background. This 2.7 Kelvin radiation, the residual "cooled down" photons left over from the Big Bang, lies at the lowest end of the energy scale, a few electron volts. The goal is to measure variations as small as a few micro-Kelvins in the CMB temperature and the degree of its polarization as one scans across the sky. As we described above in the paragraph on Glenn Starkman's work, details of the "power spectrum" provide clues to the formation of early structure in the universe.

Fig. 18-11
John Ruhl.

The key to clear viewing of the microwave sky is to get your detectors "high and dry", i.e. above the atmosphere and away from water vapor. Recall that in the 1960's, Glenn Frye and his group flew their spark chambers on high-altitude balloons over Texas and Australia, in search of cosmic gamma rays (Chapter 8). A half century later, the Boomerang collaboration (Balloon Observations Of Millimetric Extragalactic Radiation ANd Geophysics) has launched high-altitude balloon flights which circle the south pole. Suspended from the balloon are a 1.3 meter diameter telescope and an array of low-temperature bolometers ("heat" detectors). In a 2005 paper, the Boomerang team reports on the most recent flights, presenting the most detailed power spectrum to date. The paper concludes: "We characterize a series of features in the power spectrum, which extend to multipoles $\ell > 1000$, consistent with those expected from acoustic oscillations in the primordial plasma in the context of standard cosmologies". This means that, down to regions of the sky as small as a third of a degree, the observed pattern of tiny temperature variations is well explained by an expansion in the early universe including a few bounces.

John Ruhl's team is also involved in a ground-based experiment set up at the South Pole: the Arcminute Cosmology Bolometric Array Receiver (ACBAR). The expectation is that this detector, installed on the 2 meter diameter Viper telescope, has 2.5 times better angular resolution than Boomerang. And, neither least nor last, the group is also involved in the construction of the 10-meter diameter "South Pole Telescope". The emphasis here will be the study of galactic clusters and the role of "dark energy" in their formation.

Shutt – wimps too

Tom Shutt moved his research program from Princeton to Case in early 2005. Like Dan Akerib, Shutt's principal interest is the detection of WIMP dark matter. Each group is in the race to be the first to nail down a clear signal of interactions caused by these evasive particles. Akerib and the CDMS collaboration have set upper limits on WIMP flux by using kilogram-sized cryogenic detectors. Shutt and his team are members of a large collaboration called XENON which will chase down WIMP's with a ton of liquid xenon. The detector will be placed in the Laboratori Nazionali del Gran Sasso, an already existing large complex adjacent to an autostrada tunnel deep under the Appenines in central Italy. The plan is to begin with ten 100 kg modules, each with a very sophisticated signal read-out system which simultaneously picks up the electrons, photons and recoil xenon nucleus. The expected event rate, given the presumed density of WIMP's in the Milky Way, is ten events per year. The Case group has built and successfully tested a 35 kg test module. The WIMP Race at Case is underway.

Fig. 18-12
Tom Shutt.

What next

It will be fun to watch the research program in the CASE physics department as it moves ahead. What research will occupy its members in 2050, or maybe even 2015, is beyond anyone's guess. Physics is at the heart of our understanding of all natural phenomena and it will continue to be at the center of the university. The materials science programs, with innumerable links to applications, will certainly continue to flourish. With orders-of-magnitude improvements in the speed of computation, atom by atom, and even electron by electron, calculations will be possible. New materials will be conceived and analyzed by computational physicists before being turned over to the people who will build them. The same is true for areas like medical imaging which is driven by computing power. It is almost certain that physicists will become ever more involved in medical science: not just for diagnostics, but for treatment. The decoding of the various signals from space by advanced computational analysis will continue to lead to a better understanding, not only of how the universe was formed, but of the very nature of its building blocks. In particle physics and field theory, the computer's ability to find the needle in the haystack or to carry out calculations to ever higher orders will be key to new physics. *WRC, WRU, CSAS, CIT, CWRU, CASE* physics will be there, and with continued leadership and support, it will thrive.