The Chameleon in the Cosmos
Letter from the Chair

Greetings,

I am now writing again after my first year as Chair of Physics. It has been a good year, and an exciting year, with changes in research, faculty and staff. We are recruiting faculty who will take the department in new directions. At the same time, we are saying farewell to some valued members of our department. The result is sadness, loss, but also exciting opportunities for change and growth.

The most significant research from the department this year was Jens Gundlach’s torsion balance experiment, which provided the most precise measurement to date of Earth’s mass. More groundbreaking discoveries are on the horizon. The properties of neutrinos are one of the big physics issues before us. The long-standing problems of defining the number of neutrinos from the sun has indicated problems with either our solar models or with the fundamental physics. After sixteen years of planning we expect information from the Sudbury Neutrino Observatory and from Super-Kamiokande (see the 1999 newsletter) to solve the situation. Already the Super-K discovery of a neutrino mass changes fundamental models. Several members of our faculty are leaders in the Sudbury effort, which you can read about on page four.

The first of the two faculty members who retired last year is Vic Cook from the Experimental Particle Experiment group. Vic retired in June, and is spending his first year of retirement at the National Science Foundation overseeing the LIGO project to detect gravitational waves at Hanford. The other retiree is Ed Stern in the Condensed Matter Experiment group who left us in August. Ed joined the faculty in 1985, and he will continue as head of the PNC-CAT which runs an Advanced Photon Source beamline at Argonne National Laboratory. On page nine, you can read more about Cook, Stern and other retiring faculty and staff.

Among the distinguished visitors to the Department last year, we had Andy Strominger, Ed Witten, and Paul Steinhardt, each of whom gave a Boris Jacobsohn Lecture. Andy Strominger talked about the understanding of black holes which string theory provides; Ed Witten gave a joint mathematics-physics talk to a packed house on how string theory is related to mathematics and to our understanding of fundamental physics; and Paul Steinhardt gave two talks: one on quasi-crystals, and one on cosmology.

Our faculty continue to be recognized for their accomplishments. Alexi Ankudinov, Vitaly Efimov, Jens Gundlach, Wick Haxton, Paula Heron, Lillian McDermott, Marjorie Olmstead, Ed Stern, Chris Stubbs, and David Thouless all received significant awards during the past year. The most outstanding of these were the Onsager Prize which David Thouless received for outstanding work in statistical physics, and the Oersted Medal which Lillian McDermott will receive in January for her work in Physics Education.

Another form of recognition is when other universities attempt to recruit our faculty. (We are somewhat ambivalent about this!) This year we were pleased to see our recognition of David Kaplan’s and Ann Nelson’s work confirmed by the efforts of MIT and Berkeley to recruit them. We were even more pleased to be able to successfully persuade them to stay. Ann and David are now respectively chairing committees to search for faculty in elementary particle theory and in nuclear theory, and we are looking forward to further strengthening our efforts in those fields.

In memory of her husband, Professor Kenneth Young who passed away two years ago, Christopher Young established a fund to award fellowships to outstanding new graduate students. We were very pleased to be able to name Laura Stonehill, who came to us from Pomona College, as the first Kenneth Young Fellow.

The achievements of the past year would not have been possible without the support of alumni and friends of the department. Some of our most notable accomplishments — recruiting extraordinary faculty, rewarding our top faculty, preparing the next generations to contribute meaningfully to our society — have only been possible because of the funds which our friends provide. Both the endowed funds which make the recruitment and the awards for outstanding achievement possible, and the discretionary fund, Friends of Physics, which supports the activities which give cohesiveness to the department are essential. Your continued support is deeply appreciated.

Sincerely,

David G. Boulware
The Chameleon in the Cosmos

How do you catch a neutrino?

The lightest bit of matter in the universe, a neutrino can travel through a light-year of lead without leaving a sign. Three kinds of neutrinos exist, but they can transform themselves without warning. Imagine that someone threw a baseball at you but it turned into a football by the time you caught it. Neutrinos may act the same way.

Just another small challenge for physicists.

Up in Sudbury, Ontario, in Canada’s Great White North, a group of international scientists have dug one of the world’s biggest holes. They’ve filled it with 7,700 tons of the world’s cleanest water, in which floats the world’s largest plastic ball. Inside of the ball is heavy water (D$_2$O), eleven hundred tons of it. The entire experiment is more than a mile underground, in a busy nickel mine.

The Sudbury Neutrino Observatory (SNO) has been taking baseline data for a year already. Soon, when all its instrumentation is in place, the scientists who have spent the last sixteen years building the observatory hope that something unprecedented will happen. That neutrinos born in the heart of the Sun will travel 93 million miles through space, air and rock down to their waiting observatory. That some of those neutrinos will smash into heavy water nuclei, breaking them up like billiard balls that turn their neutrino detectors on like a Christmas tree.

SNO will be able to spot about 20 of the trillions of neutrinos which pass through it each day, with the help of data acquisition software written by UW physicist John Wilkerson and his team. That doesn’t sound like much, but it’s fifty times more than can be spotted at most other observatories.

“Hold your breath,” says Hamish Robertson, UW physicist and a leading member of the Sudbury Neutrino Observatory (SNO) team. “We will have something to say by next December.”

There are gadzillions of neutrinos in the universe... so many that they are impossible to count. At any given time, there are ten million of them in your body. Until recently, physicists did not know whether neutrinos possessed any mass at all. The Japanese neutrino detector Super-Kamiokande (see 1999 Physics newsletter) has now proven to physicists that one type of neutrino does have a very small mass. The other two, however, are still an unknown quantity. Will the universe keep expanding? Or will it shrink into oblivion in some far-off future? Seeing if the other two types of neutrinos have mass — and how much mass — will help physicists answer this question. “Then we can figure out how much of the universe they make up,” says Robertson.

Scientists believe that all three types of neutrinos will be visible at SNO. “The big advantage of SNO,” says UW physicist Steve Elliott, “is that it can detect a reaction which measures

Workers at the partially-finished SNO observatory.

Some of the 9,500 SNO phototubes.
SNO FACTS

Where is SNO?
Inside the Creighton mine, an active nickel mine in Sudbury, Ontario.

Who thought up SNO?
Herbert Chen at UC Irvine, in 1985. (He died in 1987.)

What’s so special about SNO?
No other neutrino observatory uses heavy water (deuterium oxide). It's too expensive and too rare. But neutrinos like heavy water better than the usual stuff. Because of the heavy water and its specially designed detectors, SNO should be able to see solar neutrinos interacting in a way that's never been spotted before — the neutral current reaction.

When a neutrino smashes a deuterium nucleus into its component proton and neutron, you get a neutral current reaction. All three known types of neutrinos can spark this reaction.

SNO can already detect the charged current reaction, where a neutrino enters the deuterium nucleus and changes the neutron inside of it to a proton. Only electron neutrinos can cause charged current reactions.

the total number of neutrinos escaping from the Sun.” In order to see the neutral current reaction (see SNO Facts sidebar), Hamish Robertson invented special detectors which the UW is now building for SNO.

Down in the basement of the UW’s Physics/Astronomy building, Elliott is overseeing the construction of the last few neutral current detectors (NCDs). They are 8-foot tubes, about 2 inches in diameter, made of the world’s purest nickel and filled with helium-3 gas. The mantra for this laboratory is the same as for the SNO observatory itself: Cleanliness rules.

“The most difficult part of all solar neutrino experiments,” says Elliott, “is radioactive background.” Besides the uranium and thorium which exist in all building materials, Elliott worries about people tracking in tiny bits of polishing compound from the glass shop down the hall. “Just a few sand grains could swamp the detector signal,” he says. After the tubes are cleaned and welded, the rest of the work takes place inside a clean room. Radon exposure from the air, another potential contaminant, is carefully monitored.

By next March, all 300 neutral current detectors should be completed. The UW team will take them up to Sudbury and transport them underground, where a remotely-operated submarine operated by UW graduate student Miles Smith will deploy them into SNO.

Though the NCDs are not yet deployed, SNO is already tracking neutrinos. “We can’t help it,” says UW physicist Tom Steiger. “There’s no way to turn them off.” Besides recording baseline data, the observatory is tracking electron neutrinos through the charged current reaction (see SNO Facts sidebar). While the most eagerly anticipated SNO data will come with the NCDs, watching neutrinos pass through the observatory is still a rush. “You can see the data coming in from ten thousand photomultiplier tubes,” says Miles Smith. “It’s quite exhilarating, all those green LED lights flashing.”
Who paid for SNO?
The Canadian government loaned the project $300 million worth of heavy water. Without that donation, the SNO project would not have been possible. In addition, the Canadians paid for 75% of SNO’s construction.

The U.S. Department of Energy funded the UW’s contribution to SNO as well as the contribution of four other U.S. institutions. DOE also paid 25% of the construction costs.

What are the parts of SNO?
Heavy water inside the world’s biggest plastic sphere, 40 feet in diameter and 2 inches thick.
The neutral current detectors will be deployed inside the sphere.
Outside the sphere sits a steel structure lined with 9,500 phototubes which can detect light produced by neutrino interactions.
Surrounding the plastic sphere is 7,700 tons of regular water, shielding SNO from background radiation.
Aside from the occasional muon and gamma ray, only a neutrino can get through all this!

For the last six years, UW graduate students and post-docs have helped to build SNO’s neutral current detectors. Now that SNO is operating, they have travelled to Sudbury to monitor the observatory. Graduate students like Karsten Heeger are even beginning to analyze the first SNO date.
“Keep the force of this experiment are the graduate students,” says Peter Doe, the UW physicist who supervised the building of SNO’s acrylic vessel. “They’re the life and soul of it.” The entire UW team — students and faculty — come from the UW’s Center for Experimental Nuclear Physics and Astrophysics (CENPA).

One summer, Miles Smith and Karsten Heeger went to see the aurora borealis when they were up in Sudbury. “We stood in awe for half an hour,” says Smith, “and then went back to working on neutrinos.”

JUST ANOTHER SNO DAY

It’s 20 degrees below zero, and still dark, when you show up at the shaft station. Fifty miners stand with you on the platform as you wait for the “cage” — the elevator that will take you all to work. Like everybody else, you’re wearing a miner’s uniform. “Catch any of those neutrinos yet?” one miner jokes.

The cage arrives and you all cram in. First stop, 5,000 feet down. Some miners get out, wishing you a good day. The rest are laughing and joking and cursing. You mentally review the safety procedures you learned before they even let you in here. “You have to be certified as a contractor in Canadian mines to go into the lab,” graduate student Kathryn Shaffer says. It’s a week of serious training: you’ve got to know what to do if rock shifts underground, and how to barricade yourself against fire.

Second stop, 6,800 feet down. Out you go. First thing you notice is how warm it’s gotten... about 80 degrees F and sometimes even hotter. You walk down a narrow, dimly-lit tunnel... a “drift” in minespeak. Half a mile walk, you check the air quality. Carbon monoxide, anyone?

Another half a mile and you’re at the entrance to the SNO lab. First you shed your mining clothes and take a shower. When you get out, there are clean blue nylon coveralls, a hairnet, clean workboots and safety glasses to wear. In here it’s air-conditioned. You can still hear blasting from other parts of the mine, and mini-earthquakes caused by shifting rock.

Finally, after stepping into a “phone booth” which blestes you with clean air and sucks the dust out at your feet, you can proceed into SNO’s control room.
NOBEL PRIZES

The 1999 Nobel Prizes were awarded for a fundamental, but abstract and rather esoteric research topic, which even the laureate himself had trouble explaining to his own family. (See our story in the Fall 1999 Newsletter.) In contrast, the year 2000 prize was given to Zhores I. Alferov and Herbert Kroemer “for developing semiconductor heterostructures used in high-speed and opto-electronics,” and to Jack S. Kilby “for his part in the invention of the integrated circuit.”

These inventions changed everyday life for each of us beyond recognition, within a generation. But some say that these are just that: inventions, not profound discoveries, and therefore somehow “unworthy” of the Nobel prize. I found it interesting to re-read the relevant part of Nobel’s will:

"THE WHOLE OF MY REMAINING REALIZABLE ESTATE SHALL BE DEALT WITH IN THE FOLLOWING WAY:
THE CAPITAL, INVESTED IN SAFE SECURITIES BY MY EXECUTORS, SHALL CONSTITUTE A FUND, THE INTEREST ON WHICH SHALL BE ANNUALLY DISTRIBUTED IN THE FORM OF PRIZES TO THOSE WHO, DURING THE PRECEDING YEAR, SHALL HAVE CONFERRED THE GREATEST BENEFIT TO MANKIND. THE SAID INTEREST SHALL BE DIVIDED INTO FIVE EQUAL PARTS, WHICH SHALL BE APPORTIONED AS FOLLOWS: ONE PART TO THE PERSON WHO SHALL HAVE MADE THE MOST IMPORTANT DISCOVERY OR INVENTION WITHIN THE FIELD OF PHYSICS..."

So inventions clearly qualify. The only suspect bit is the one about “during the preceding year.” But this has been interpreted liberally, not literally, since the very beginning, and one assumes Dr. Nobel would agree.

On the Internet, please note the very interesting and educational display on the “Century of Physics” produced by the American Physical Society. This is a fairly complex set of web pages, well worth exploring. A set of “hard copy” posters, each illustrating a specific decade of the last century, is available. The Physics Department Aesthetics Committee is in process of mounting this set in the form of a long-term exhibition on the first floor of the Physics-Astronomy Building. Watch the newsletter’s home page for an announcement of the exhibit opening.

And speaking of Aesthetics: we have displayed, in the vestibule of the Ronald Geballe Auditorium, a new sculpture called Tulus, by Seattle artist (and molecular biologist) Lee Anandan. Tulus was created after Lee heard a radio discussion of materials available on the surface of Mars; a descriptive leaflet explains some interesting physical processes utilized in the act of creation.

Aesthetically, Tulus provides a nice complement to our famous (or infamous) "peanut." Art, as much as Physics, is a question of taste.

After a student of Darius Milhaud invoked this argument when discussing her failing grade in musical composition, the Master said: "Yes my dear, and you have BAD taste."

So, there you have it.

Vladi Chaloupka
It’s a new century, and while we look ahead to new research and new faces, we also say goodbye to some old friends. Several members of the physics faculty have just retired from the UW. We honor them here.

**VICTOR COOK** joined the UW in 1963, and has been researching experimental high energy physics ever since. He also served in key administrative positions at the National Science Foundation, including a post as program officer for elementary particle physics. Victor Cook currently manages the Laser Interferometer Gravity-Wave Observatory at Hanford (LIGO), which looks for gravitational waves of cosmic origin.

**ROBERT D. PUFF** began his UW career in 1962 as a nuclear physicist. He gradually expanded his interests to various theoretical problems of condensed matter, and many-body physics in general. Currently, Puff is participating in a highly interdisciplinary development of a novel technique to detect radiation by the damage it does to a sample of DNA. “Our faculty meetings won’t be anywhere near as interesting without him,” says Vladi Chaloupka.

**CHUCK ROBERTSON** joined the UW in 1990 as a senior lecturer. Active in physics education both regionally and nationally, he has been a leader in the American Association of Physics Teachers. Aside from teaching Introductory Physics courses, labs and tutorial sections, Robertson has been an invaluable help to the department, coordinating the assignments of teaching assistants and organizing the Blair Outing. His enthusiastic role in the Final Friday Flings, a monthly departmental social event, will long be remembered.

“Science has an aspect of faith to it. You have to believe the methods you’re using to understand nature will be successful. Standing on the shoulders of giants, so far we physicists have been lucky. We’re all devoting a large amount of effort and time based on a faith that our present methods will continue to yield results.”

**EDWARD A. STERN** came to the UW in 1965. Over his career he has played a leading role in experimental condensed matter research. His work has many applications including targeting environmental toxins and developing improved catalysts. His honors include Guggenheim, Fulbright and NSF Postdoctoral fellowships and the B.E. Warren Diffraction Physics Award, among others. An award was named after him for his development of the x-ray absorption fine structure technique for structure determination on an atomic scale. Stern continues to direct a group of institutions which are developing beam lines at the Advanced Photon Source near Chicago, the biggest x-ray source in the US. A proud grandfather of three (with another on the way), he also plans to devote some time to improving physics education for children.

**A MASTER CRAFTSMAN**

“Seems like I always ended up making stuff for people,” says John Roze, who is retiring in March after twenty years as manager of the physics shop. Roze helped to build the single particle traps that Hans Dehmelt used in his Nobel-prizewinning research. “John had to be really clever to build accurate parts with, essentially, stone knives and bear skins,” says Dean Farnham, a former UW post-doc with the atomic physics group. “We were striving for one ten-thousandth of an inch accuracy with some tiny, strangely shaped objects.” Now computer-assisted lathes can execute much of the work that Roze did with such love and patience, enabling the physics shop to mass-produce parts that would be impossible five years ago. “It was a different pace back then,” Roze says.
Our Students and Their Research

Much if not most research at a university is done by the graduate students. In order to make our annual compilation of the theses more informative and interesting, we have added some very brief, plain-language descriptions. For a detailed description of our graduate program see http://www.phys.washington.edu.

**PhD DEGREES GRANTED AUTUMN 1999 - SUMMER 2000**

**Alexander D. Cronin:** New techniques for measuring Atomic Parity Violations (Prof. Hackel). Atomic tests of fundamental physics are complementary to tests at high energy accelerators. Several new experiments are proposed and explored.

**Marc P. Geissbuhler:** Interfacial Crystallography of Water on Calcite (Prof. Sorensen). The surface of calcite is found to be covered with a single molecular bilayer of solid ice. So, at the molecular level, there is actually a layer of the infamous polywater, or of Kurt Vonnegut's ice-9!

**Lian He:** A Measurement of the Branching Ratio of the D Meson Decay into a Tau and a Neutrino (Prof. Wasserbaech). Rates of decay of particle containing heavy quarks are tested against the prediction of the standard model.

**Christian H. Kautz:** Identifying and Addressing Students' Difficulties with the Ideal Gas Law (Prof. McDermott). Student understanding of pressure, volume, temperature and number of moles is investigated; several conceptual difficulties are related to incorrect microscopic models.

**Andre T. Krammer:** Computational Studies of Protein-Membrane Interactions and Forced Unfolding of Proteins (Prof. Vogel). New simulation methods are utilized to address questions about complex biological systems that are inaccessible to conventional experiments.

**Michael E. Loverude:** Investigation of student understanding of hydrostatics and thermal physics (Prof. McDermott). Conceptual difficulties with topics in introductory mechanics affect understanding of more advanced topics courses; supplementary curriculum is developed and proven effective.

**Michael W. Moore:** Measuring the second Harmonic Amplitude of an Oscillating Torsion Pendulum to Detect Small Forces (Prof. Boynton). A novel, extremely sensitive apparatus for high-precision measurements of the strength of gravity was devised and tested.

**Bede Pittenger:** Nanomechanical Investigation of Ice Interfaces via Atomic Force Microscopy (Prof. Fain). Ice surfaces are studied by indenting them with atomic force microscope tips!

**John Y. Putz:** A measurement of the branching fraction of Ds Meson (Prof. Rothberg). Four million decays of the Z particle (acquired at the LEP accelerator near Geneva, Switzerland in 1991-95) were used to measure the rate of a particular rare disintegration.

**Roberto C. Ramos:** Liquid-vapor coexistence in two-dimensional 3He-4He mixtures (Prof. Vilches). The adsorption, liquid-vapor coexistence, critical temperatures, and T=0.2K liquid densities are investigated in single atomic layer quantum isotopic mixtures.

**Gautam Rupak:** Nuclear Effective Theory and its Applications (Prof. Savage). Calculations of light-element abundance are shown to agree with experimental data, contributing to understanding of Big Bang nucleosynthesis.

**Michael H. Schacht:** Spin State Manipulation and Detection and Parity Violation in Single Trapped Ions (Prof. Fortson). A novel experiment manipulates spin state of a single trapped ion; same method will be used in a new, high-sensitivity parity violation experiment.

**William R. Schief, Jr.:** Phase Transitions in Two-Dimensional Model Systems (Prof. Vogel). Experimental investigation of lipid and protein monolayers at the air/water interface: this is "biological condensed matter nanophysics!"

**Grace Sun Siswanto:** Simulations of platinum growth on Pt(111) (Prof. Jonsson). The mechanism and rate of crystal growth processes were studied and long-timescale simulations carried out in order to compare with laboratory experiments done by others.

**Ronald S. Steinke:** The derivation of an Effective String Theory from a Field Theory Containing Vortex Solutions (Prof. Baker). This work provides new understanding of the relationship of the spin of mesons to their mass (the famous Regge trajectories).

**Blas P. Uberruaga:** Diffusion in semiconductors: A theoretical study (Prof. Jonsson). Mechanism and rate of diffusion in silicon and germanium were studied. This is important for fabrication of even smaller semiconductor devices.
Our program in Applied Physics grants Master of Science degree to students who complete an approved series of courses (offered in the evenings, to accommodate students with jobs. Our enrollment includes students employed by Boeing, Microsoft, US Navy, and many other companies and organizations in the Puget Sound region). To conclude the program, students perform and present a research project under supervision of a faculty member. For detailed information about the program see http://www.phys.washington.edu.

**MS DEGREES GRANTED SUMMER 1999 - AUTUMN 2000**

**D. Eric Aston:** Pulsed-Force Mode Atomic Force Microscope in Liquid Environments (Prof. Fain). A new mode of operation of the atomic-force microscope was used to explore the surfactants and other surface modifiers.

**Michael D. Beard:** Developing Computer Controlled Data Acquisition Systems for the Senior Labs (Prof. Sorensen). The LabVIEW environment was interfaced to four experiments, enabling much more immediate access to the data.

**Justin Cobbs:** Sonoluminescence: Observations and Current Theories (Prof. Chaloupka). Sonoluminescence (production of a very brief flash of light by a sound wave) was observed experimentally, and current theories of the effect were discussed.

**Ruth A. Fogelberg:** Vertical Force Between a High Temperature Superconductor and Permanent Magnet (Prof. Seidler). An apparatus for measuring this force was designed and tested. Applications could include development of nearly frictionless bearing.

**Stuart Hagler:** Towards an Inexpensive Small-area AC Calorimeter (Prof. Vilches). Efforts to cheaply measure the heat capacities of samples by periodic (AC) power input are described.

**Matthew C. Miller:** Study of Scattering from Fractal Surfaces (Prof. McDermott). Two methods of studying scattering of a transverse electromagnetic wave from random rough surfaces are applied and compared.

**A. Cody Young:** Can Somatic Cells See? (Prof. Sorensen). The role of the “centriole” (a tiny organelle in the somatic cell) in the detection of infrared light is explored.

Congratulations, all!
A Designing Man


All except Ingalls, who liked it so much he changed his major. And liked UW so much, he returned after graduate work at Carnegie Tech and a postdoctoral stint at Illinois.

During his thirty-six years on the UW's physics faculty, Bob Ingalls became one of the principal "architects" of the Mossbauer effect, which states that some gamma rays from nuclei can be emitted and re-absorbed without recoiling. The Mossbauer effect makes it possible to study extremely small changes in the energy of gamma rays that are caused by gravity, high pressure, and changes in the environment. Ingalls is renowned for applying the Mossbauer effect, and more recently, x-ray absorption spectroscopy, to studying materials at high pressure.

"It's very exciting that it's possible to squeeze materials into such small dimensions and cause them to undergo all sorts of changes," Ingalls says. He explains that metallic iron, for example, will lose its magnetism when squeezed. Other materials become will become superconductors, insulators, or undergo other changes of state. Ingalls has written about the Mossbauer effect in the Encyclopedia of Physics.

While architecture led Ingalls to physics, physics also led him back to architecture. "I've been dabbling in quasi crystals," says Ingalls, "which don't repeat like regular crystals, but still form a pattern." He displayed these patterns at a UW condensed matter seminar in the old Physics building in 1990. A colleague suggested he show them to the architects of the new building. The next thing he knew, they had decided to use quasi crystal patterns for the window designs. "That's what you see if you go into B-wing," says Ingalls. "There's over a hundred such windows in the stairwells."

Ingalls retired from the UW's physics faculty in December, but some things don't change. He plans to keep teaching at a reduced level. He will also continue to play his bassoon. Ingalls has been a freelance musician for over fifty years.

"As an undergraduate, I funded my education by playing in the Seattle Symphony," says Ingalls. "I got to play under Leopold Stokowski, Arthur Fiedler and Igor Stravinsky, among others."

Ingalls doesn't plan to quit long-distance running, either. He is proud to have joined a team which included his children and grandchildren, and completed the 195-mile Hood to Coast relay race this past summer.