Southern Skies and Cosmic Questions

How big is the observable universe? What is it made of? Why does space repel itself? Eminent theoretical astrophysicist and new Physics Department Head Ed Bertschinger deftly guides us toward the answers to these 'cosmic questions,' when he takes us along an MIT alumni journey to the twin Magellan telescopes in Chile.

By Edmund Bertschinger

Viki Weisskopf: Searching for Simplicity in a Complicated World

One of the most respected, and beloved, physicists of the 20th century, MIT's Viki Weisskopf was a figure renowned in his own time. Here, award-winning MIT science historian, physics lecturer, and author David Kaiser delves a bit deeper into the fascinating story of this physics legend.

By David Kaiser
MESSAGE FROM THE DEPARTMENT HEAD

Dear Members of the MIT Physics Community,

I am delighted and privileged to be appointed the next Head of the MIT Department of Physics. The Department is in excellent shape thanks to Marc Kastner’s leadership and the efforts of our wonderful faculty, staff, students, and friends. I’m delighted that Marc has now become Dean of Science. We thank Marc for his tremendous accomplishments on behalf of the Physics Department and we wish him the very best in his new role. Visit the News & Events section for an interview with Marc on highlights of his nine-year tenure as Department Head. I am also grateful to Tom Greytak, not only for his years of service as Associate Head for Education, but for serving as Interim Head while I am on sabbatical during the Fall 2007 semester.

For those of you whom I’ve not yet had the pleasure of meeting, I’m a theoretical astrophysicist with a passion for understanding how the universe works. As a member of the MIT Kavli Institute for Astrophysics and Space Research, I lead a research program studying the mysteries of dark energy and dark matter. My group investigates the formation of cosmic structure after the big bang, the physics of dark matter both in the early universe and in forming galaxies, and the physical processes governing matter and radiation close to black holes. My research students at the high school and undergraduate level have won national prizes for their work, including First Prize in the Intel Science Talent Search. My former Ph.D. students now hold tenured faculty positions at Harvard, Columbia, U. C.-Berkeley, and other fine universities.

I’m also passionate about education. I enjoy teaching classical mechanics, electromagnetism, quantum mechanics, relativity, and cosmology. Our undergraduates are extraordinary. I’m thrilled to report that the class of 2007 had more physics S. B. degrees than at any time in the last 18 years. Eighteen of these 85 graduates were nominated for Phi Beta Kappa—29% of all nominees Institute-wide! Ten of our alumni have won Nobel Prizes (five since 1997), and many others are pioneers and leaders of industry.

It’s exciting to lead a Department that is full of so many outstanding teachers. This past year, Eric Hudson received the Department’s Buechner Teaching Award for his work in the TEAL active-learning format of freshmen electromagnetism; Alexander van Oudenaarden was awarded the School of Science’s Excellence in Graduate Teaching prize; and emeriti faculty Tony French, John King, and Robert Hulsizer were
co-recipients of the American Physical Society’s Excellence in Physics Education Award. Another especially exciting award received by one of our many distinguished emeriti was the 2006 National Medal of Science to Lester Wolfe Professor of Physics Emeritus Daniel Kleppner. Don’t miss the Faculty Notes section for a complete listing of all our outstanding faculty honors and promotions.

In my twenty-one years on the MIT faculty, I’ve had the privilege to work with and learn from many great physicists who have helped me grow as a scientist, educator, and person. One of the most influential for me and many others was Viki Weisskopf. As Department Head, as Director General of CERN, as a colleague and mentor, Viki played a pivotal role in shaping the MIT Physics Department. David Kaiser tells the story in his wonderful article about Viki in this issue.

The last year has been a great one for our Department. Our administrative and educational offices, junior lab, Center for Theoretical Physics, and theoretical Condensed Matter Physics group have now moved into the beautiful new Green Center for Physics. I’m deeply grateful to Neil Pappalardo for his generous support for the Green Center and other projects. Neil is interviewed in this issue’s Giving to Physics section, and it’s a fascinating story. This fall we will hold a special celebration inaugurating the Green Center. If your travels bring you to Cambridge, I encourage you to come visit our new home. You will be amazed!

As Marc notes in his interview, this year for the first time we were able to offer most of our incoming graduate students a fellowship. I am deeply grateful to George Elbaum for his offer to match every dollar given to Physics for fellowships, and to all those who have provided fellowship funds. These donors are members of the Patrons of Physics Fellows, a society created to recognize the generosity of those friends and alumni who make it possible for the Department to recruit and support the very best graduate students with a full fellowship.

During the last several years I’ve discovered how wonderful it is to reconnect with alumni. Two of the most enjoyable and exciting trips I’ve ever taken have been to Chile through the MIT Alumni Travel Program. You can find my trip report, Southern Skies and Cosmic Questions, in this issue.
As Department Head, I plan to build on our success while addressing the continuing challenges. The Green Center and our Pappalardo Fellowships program will both help us increase the unity of physics at MIT and to recruit new talent. That talent must draw from underrepresented groups more than ever before; we must recruit more women and minority graduate students and faculty members. I know there are strong candidates because many earn MIT S. B. degrees.

My highest priority for fund-raising is to extend the funding of our graduate fellowships to every first-year student. Another priority is to raise private support for faculty start-up packages and the facilities used by our junior faculty, including the Magellan Telescopes. The continued support of our alumni and friends in these endeavors is critical to sustaining our strength.

I look forward to getting to know as many of you as possible. Your comments are always welcome. My email is edbert@mit.edu, and I look forward to hearing from you.

With best regards,

Edmund Bertschinger

Edmund Bertschinger
Head, Department of Physics
Before he moved downstairs to his new office in Building 6 as the next Dean of the School of Science, outgoing Department Head Marc A. Kastner met with Physics and Mathematics Development Director Elizabeth Chadis and shared a few reflections on some of the highlights of his nine year tenure.

SUPPORT OF ALUMNI & FRIENDS

Elizabeth Chadis: Marc, as you review your major accomplishments during your tenure as Department Head, of which are you most proud?

Marc Kastner: Physicists are always most proud of discovering something that no one knew before. When I began my tenure as Department Head, I discovered there were many alumni and friends who cared deeply about the Department and truly wanted to help us. I don’t think previous department heads were aware of the depth of this wellspring of positive feelings, and one of the things that I am most proud of is eliciting the support of our alumni and friends.

“As I came to know Marc, I could see that in spite of his easy manner, there is a determination and strong sense of purpose, although he doesn’t come across as pushy or assertive. I have tremendous respect for his management skills; he always gives credit to where the work is being done. I find this a tremendously admirable trait. I truly appreciate Marc and enjoy his friendship.” —George Elbaum (AA ’59, SM AA, NU ’63, PhD NU ’67); Member, Physics Visiting Committee; Charter Member, Patrons of Physics Fellows

THE GREEN CENTER FOR PHYSICS

EC: After more than 20 years of stops and starts, the Green Center for Physics is now a reality. Tell us some of the twists and turns of that story.

MK: I walk through the Green Center once a day just to remind myself that it’s there. And its history is truly amazing. For decades we have needed a place on campus that could be identified as the ‘Physics Department.’ But from the 1960s onward, every attempt had failed. In the 1980s, Cecil Green (1923–2003) gave the Department money for a building renovation, but it still didn’t happen. Soon after I became Department Head in ’98, we decided that we could accomplish our goals by renovating part of the Main Group—buildings 1 through 10—which will be 100 years old in 2016. As a first step toward accomplishing this, we reached an historic agreement with the Department of Materials Science & Engineering (DMSE) to trade space. As far as I know, no two departments had ever agreed to trade space at MIT, let alone departments from different schools within the Institute.

A critical component of the new renovation plan was to provide a shared space to create and support exciting new collaborative and teaching opportunities for two intellectual powerhouses within the Department: the

THE KASTNER YEARS 1998–2007

Marc Kastner with longstanding Department supporter and alumnus Bill Layson (SB MechE ’56, PhD Physics ’63).
Center for Theoretical Physics and the Condensed Matter Theory Group. However, at this point MIT entered a difficult fiscal period and it did not look good for the Physics Department’s new space initiative. That’s when the critical intervention of Neil Pappalardo (EE ’64) came, where he offered to give us $5 million, if we could raise an additional $5 million. And then, amazingly, alumni and friends immediately began to respond and helped us to meet Neil’s challenge in less than one year.

There was one final hurdle, however. As construction costs kept rising and threatened the project’s successful implementation, it was left to new MIT President Susan Hockfield to make the decision to move forward with the project. It was one of her first major decisions as President, and it took tremendous courage on her part. Fortunately, the end result is simply a magnificent achievement, and nothing less than astonishing.

“Sitting in my new office in the Green Center for Physics, I marvel at the wonderful space and dream about new research opportunities, now that particle and condensed matter theorists see each other on a daily basis. We owe all this to Marc’s vision and leadership.”
— Patrick A. Lee, William & Emma Rogers Professor of Physics; Division Head, Atomic, Biological, Condensed Matter and Plasma Physics

“One of the most profound realizations of late twentieth-century physics is that we can only understand elementary particles by taking into account the material (i.e., space-time, regarded as a dynamical substance) they inhabit; and that conversely we can only understand the behavior of materials by taking account of their excitations, quantized into particles such as phonons and polarons. Several great discoveries have already resulted from the ensuing dialogue between particle physics and condensed matter physics. The unification of our theoretical groups reflects the unity of physics; making a whole greater than the sum of its parts.”
— Frank Wilczek, Herman Feshbach Professor of Physics; 2004 Nobel Laureate
DEPARTMENTAL RESEARCH & NOBEL PRIZES

EC: What, for you, were some of the most memorable occasions, or developments, while Department Head?

MK: I’ll always remember being awakened at 6:00 a.m. to learn we’d won a Nobel Prize [Wolfgang Ketterle, 2001]. When I think about it, I realize I’ve hired more than one-third, almost one-half, of the active faculty in the Department. I’ve hired Frank Wilczek, who became the 2004 Nobel Laureate, and others who may win the Nobel Prize in the future. I’m very proud of all the wonderful research the faculty is doing. I’m also proud of our postdoctoral Pappalardo Fellows in Physics, and the way they’ve used their unique opportunity for independent research to produce exciting, innovative results. In a very short time, this program has become one of the most famous and prestigious of its kind within the international physics community.

“Ever since becoming a member of the MIT physics community, I’ve always felt I could count on Marc’s support. And I was right. He not only helped my research flourish, but gave me every chance to grow as a faculty member through mentoring, teaching opportunities, and other Departmental activities. Most of all, I’ve always felt that he was genuinely interested in seeing me succeed, and this, in turn, was a strong motivation for me to do my very best.”

— Gabriella Sciolla, Assistant Professor of Physics and Cecil & Ida Green Career Development Professor; 2002 Pappalardo Fellow in Physics

GRADUATE EDUCATION AND RESEARCH

EC: Providing support for the Department’s graduate students has been a priority since the beginning of your tenure as Department Head. Tell us something about the results of this commitment.

MK: In the critical area of graduate education and research, I’m very proud that today we have enough fellowships to support about half of the entering class. When I started, we only had four named fellowships. Ultimately, I hope we’ll be able to offer every incoming student a one-year fellowship. In physics, having the freedom to explore the different groups and labs before choosing a research group is particularly important. I myself had a fellowship and found it enormously helpful. It’s a privilege I’d like to be able to offer all our incoming students.

I came to graduate school with a bit of apprehension about having to choose my research group right away, but the flexibility of having a fellowship in my first year enabled me to try out two different groups…. [This] has given me more confidence that my chosen research group is the right one for me.

— Chris Williams, 2006–07 Rossi Fellow
UNDERGRADUATE PHYSICS EDUCATION

EC: The class of 2007 has some impressive statistics. To what do we owe these results?
MK: The physics class of 2007 consisted of 85 S. B. students, the highest number of graduating seniors in 18 years; this makes me so happy. Just a few years ago, we were experiencing an alarming decline in the number of physics majors, so I'm delighted that we have reversed this decline. An important reason for the positive reversal in numbers is our flexible degree option, designed for MIT students who want to study physics, but plan to ultimately pursue a career outside of academic physics research. Many MIT students realize that a degree in physics is great preparation for any number of satisfying careers. Throughout the Institute, other departments are imitating this successful program.

I also think our teaching in physics is superb; members of our faculty have been regular winners of the School of Science and Institute teaching awards. When we hire new faculty, we stress the importance of undergraduate teaching for our tenure decisions.

“In helping students plan their individual programs for the flexible option, I’ve been amazed by their originality, creativity, and good judgement. I often start a conversation with Marc with an enthusiastic ‘Listen to what this student is going to do!’ ”
— Thomas J. Greytak, Lester Wolfe Professor of Physics; former Associate Department Head for Education; Interim Department Head

LOOKING AHEAD

EC: Is there anything you would like to share about the challenges that await you as the new Dean of Science?
MK: I’m excited about all the challenges ahead of me. Now that I’ve begun talking to faculty from other departments within the School, it is wonderfully exciting to learn about all the incredible research that goes on here at MIT. This is the greatest school of science in the world, and the greatest problems facing the world today are areas where people in the School will contribute to their solutions. I am just thrilled to have the opportunity to help them.
On June 9, 2006, the Department held its annual reunion for returning alumni. Once again our renowned lecture demonstration group set up a number of experiments for our guests. Bill and Lex Layson (returning for Bill’s 50th reunion!) enjoyed watching energetic particles passing though the Cloud Chamber, while David Pepperberg, Audrey Eisenmann, and John Acevedo bravely stepped into the Faraday Cage to demonstrate that charges only live on the outside of a conductor.

On September 10, 2006, Marc and Marcia Kastner hosted one of the Department’s annual highlights, the fall reception at MIT’s Endicott House estate in Dedham, MA. This is an enjoyable opportunity for faculty and staff to meet and mingle with Department friends and their families. Joining us this year were new members of the Patrons of Physics Fellows, Zoya and David Soane. We also saw Mort Goulder, Mark Mueller, Colleen and Howard Messing, Tom Frank, and Paula and Sheldon Apsell. Paula, Executive Producer of public television’s renowned NOVA science program, ‘talked shop’ with Professors Peter Fisher, Christoph Paus, and Steve Nahn.

Professor Joseph Formaggio delivered the fall breakfast lecture on October 24, 2006, where he regaled his audience with a fascinating talk on the astonishing culmination of discoveries that have led to a revolution in our understanding of neutrinos. The talk, “Staring at the Sun a Mile Underground,” was attended by more than 70 alumni and friends, including Riccardo Di Capua, Mort Goulder, and Reid Weedon.

The spring breakfast talk took place on April 25, 2007, featuring Prof. Barton Zwiebach explaining the physics of relativistic strings. String theory is a model of fundamental physics whose building blocks are one-dimensional extended objects,
strings, rather than the point particles that are the basis of the Standard Model of particle physics. String theorists hope to unify the known natural forces by showing that they all arise from oscillations of quantum strings. Alumni and friends in attendance at the Faculty Club included Sherwin Greenblatt, Martin Schrage, Karen Mathiasen, and Neil Pappalardo.

**PAPPALARDO DISTINGUISHED LECTURE IN PHYSICS**

Virginia Trimble, of the University of California, Irvine, was named this year’s Distinguished Pappalardo Lecturer in Physics, and spoke to a full house in 10-250 on “Cosmology: Man’s Place in the Universe,” on October 26, 2006. The talk’s focus was life on our planet and the different stages that brought us to our present epoch. Professor Trimble explained how changing even a little bit of the physics or cosmology might have prevented life as we know it. Joining Neil and Jane Pappalardo and Department faculty and friends for dinner afterward were Serpil and Yalcin Ayasli, Curt Marble, and Pappalardo son-in-law, author Todd Lemke. The Pappalardo Distinguished Lecture in Physics was established in 1999 in honor of Neil and Jane Pappalardo, friends of the Department of Physics who believe in broadening scientific frontiers for the good of humanity.

**AKAMAI DINNER**

On January 8, 2007, Tom Leighton (SB ’81), Professor of Applied Mathematics and Chief Scientist and Co-Founder of Akamai Technologies, and John Reed (SB ’61), retired Chairman of Citigroup, Inc., hosted a dinner for MIT’s mathematics and physics alumni employed in finance. Guests enjoyed a tour of the Akamai Network Operations Center, followed by a reception and buffet dinner. Speakers included Tom Leighton and John Reed, as well as Mathematics and Physics Department Heads Mike Sipser and Marc Kastner. We also heard from Dana Mead, Chairman of the MIT Corporation, who pointed out that fundraising will rest more and more with the Departments themselves. Guests included Erich Caulfield, Sven Heemeyer, Lisa and Bob Reitano, Garrett Stuck, and Pamela Coravos.
According to eminent theoretical particle physicist Roman Jackiw, as well as many others, the study of physics prepares you for a career in any field. On January 17, 2007, Prof. Jackiw introduced his former student, Dr. Michael Bos, Managing Director of Lehman Brothers, as a shining example. Michael described Wall Street from the vantage point of 25 years of personal experience. He noted that when he started out, “physicists and other people with scientific backgrounds were exceedingly rare. Today, scientists in finance are much more common because of derivatives—a security that refers to something else.” Derivatives are similar to quantum mechanics in that they can be looked at in a wide variety of ways. Michael next pointed out that a “physics education provides the technical apparatus to value derivatives.” He wrapped-up by saying, “if you consider leaving academia for Wall Street, do not overestimate yourself, do not underestimate yourself, and take a proactive stance…be a little bit aggressive.”

The Pappalardo Fellowships in Physics, one of the most prestigious postdoctoral fellowship programs within the international physics community, completed its eighth annual competition in January 2007 with the acceptance of three new fellows for the 2007–10 term: Jeffrey Gore of MIT (experimental biophysics), Nitya Kallivayalil of Harvard University (experimental astrophysics), and Paola Rebusco of the Max Planck Institute for Astrophysics, Germany (theoretical astrophysics).

Complete biographies, including research descriptions and publications for all Pappalardo Fellows, present, incoming, and former, can be found on the program’s web pages at web.mit.edu/physics/research. The MIT Pappalardo Fellowships in Physics program was initiated, and is sustained, by funds generously provided by Neil and Jane Pappalardo.
AN ASTRONOMICAL EVENT

On March 8, 2007, the Department held a one-day symposium showcasing its astrophysics research entitled An Astronomical Event. Through lectures, break-out sessions, and tours, faculty and Pappalardo Fellows demonstrated our recent expansion of activities into frontier areas of astronomy and astrophysics. By day’s end, the 75 attendees had a much greater appreciation of why we study black holes, gravitational waves, exoplanets, the birth of galaxies, and the cosmos itself. Alumni attending from the west coast included Bob Johnson, Rick and Ann Tavan, Juan Carlos Torres Carretero, and Randy Blotky. Other travelers included Jeff Trester, Neil Goldstein, Tom Frank, Lynne Butler, Miller Maley, and Sam and Gail Losh. Local alumni partaking of the fun included Bill Edgerly, Pierre Brosens, Joe Hrgovic, and Lynne and Eric Swanson.

PATRONS OF PHYSICS FELLOWS RECEPTION

The Department held its second annual Reception for the Patrons of Physics Fellows on April 12, 2007. The annual opportunity for graduate students with named fellowships to thank their Patrons, and share the year’s accomplishments, was attended by over fifty patrons and students. Robyn Sanderson, 2005–06 Whiteman Fellow, Sarah Vigeland, 2006–07 Whiteman Fellow, and Chris Williams, 2006-07 Rossi Fellow, spoke on their research results and how they came to study physics at MIT. Patrons in attendance included charter members George Elbaum and Mimi Jensen, as well as Joe Hrgovic, Colleen and Howard Messing, Bill Layson, Neil Pappalardo, Curt Marble, and our newest Patrons, Zoya and David Soane.
James E. Gunn from Princeton University was this year’s Distinguished Harris Lecturer. His talk, “Surveys: The Flip Side of Observational Astronomy,” took place before a full house in 10-250 on April 26, 2007. Professor Gunn discussed the desiderata for, and the impact of, such surveys, concentrating on the design and results from the Sloan Digital Sky Survey. A dinner followed at the Hotel Marlowe in Cambridge with members of the Harris and Walton families.

The Harris Lecture was established by Edith Harris in honor of her husband, MIT physics alumnus David H. Harris (SB ‘22) for a life and career dedicated to education.

On May 2, 2007, the Department held a “thank you celebration and roast” for departing Department Head Marc Kastner and Associate Department Head for Education Tom Greytak, honoring their combined 18 years of service. Adroitly emceed by Administrative Officer Heather Williams, keynote speakers included Department benefactor Neil Pappalardo, plus professors Wit Busza, Peter Fisher, and Ed Bertschinger. Development Director Elizabeth Chadis added a memorable ‘musical number,’ and a witty tribute to Tom from Education Administrator Brian Canavan nearly brought down the house in the Pappalardo Community Room, which was overflowing with physics faculty, staff, students, and friends. Some of the special guests in attendance included Kastner family members such as wife Marcia, daughters Julia and Sonia, mother Ida and sister Barbara, joined by Greytak sons and MIT alumni Matthew and Andrew and family.

Roastees Tom Greytak (left) and Marc Kastner.

Some of the overflow crowd at the Kastner and Greytak celebration.
The Department’s prestigious postdoctoral fellowship program, the Pappalardo Fellowships in Physics, held its 6th annual symposium on May 18, 2007, showcasing highlights from the research of a selection of its outstanding young fellows. Five of the current Fellows were featured in a series of talks held in the new Pappalardo Community Room, attended by a wide cross-section of members and friends of the MIT physics community. The talks explained key features of the work of Fellows Henriette Elvang (string theory), David Kaplan (experimental astrophysics), Michael Miller (experimental particle physics), Jocelyn Monroe (neutrino physics), and Jacob Taylor (hard condensed matter theory). The overflow audience included program founder and benefactor Neil Pappalardo and his wife Jane, their son Michael Pappalardo, as well as longstanding Department friends Curt Marble, Bill Layson, and Colleen and Howard Messing.

Following the presentations, departing Department Head Marc Kastner was presented with a special award by founder Neil Pappalardo and the program’s Executive Committee, naming Marc an Honorary Pappalardo Fellow. Neil pointed out that although the award was ostensibly in recognition of Marc’s long service to the program, in truth it was bestowed to provide him with a guaranteed free meal at the Fellows’ weekly luncheon events. To which the future Dean of Science quipped that he was grateful for the honor, as he “was certain it was the only way he ever could have qualified to be an MIT Pappalardo fellow.”

For more information on all aspects of the Pappalardo Fellowships in Physics program, please visit the program’s pages in the Research section of the Department’s web site at web.mit.edu/physics.
In May, Institute Professor Emeritus and 1990 Nobel Laureate Jerry Friedman led a group of MIT alumni to Switzerland to learn about high energy physics. The highlight of the trip was the opportunity to visit CERN, the world’s largest particle physics lab, or as some have described, “the coolest place in the universe.” CERN is the home of the Large Hadron Collider (LHC), a particle accelerator designed to probe deeper into matter than ever before. The group had the opportunity to see the different experiments in operation at CERN with MIT physics faculty Christoph Paus and Steve Nahn leading the way. According to Physics Department friend Mark Mueller, “CERN is like no other place that has ever existed in the history of this planet. The scale of the engineering juxtaposed with the precision of the instrumentation is so audacious as to border on the unbelievable.” Also enjoying the trip were Howard and Colleen Messing with their children, Sam and Lauren, as well as Jim and Betsy Ferguson, Joanne Mueller, and Lex and Bill Layson.

On May 10, 2007, the Department hosted a colloquium and reception in honor of Professor of Physics Emeritus Laszlo Tisza’s 100th birthday. Speakers included Institute Professor Mildred Dresselhaus, as well as Yale Professor of Mathematics Emeritus Benoît Mandelbrot, and Sébastien Balibar, Professor of Physics at the Ecole Normale Supérieure in Paris. Alumni and friends joining us included Allen Razdow, Joe Hrgovcic, and Mrs. Felix Villars.

The Department of Physics hosted a memorial celebration in honor of Francis E. Low (1921–2007) at the MIT Chapel on May 22, 2007. Guests came from all across the country to pay tribute to Prof. Low, who was remembered as an outstanding physicist, teacher, and administrator at MIT. Former students and friends sharing personal reminiscences included Gino Segre, Robert Jaffe, Mitchell Feigenbaum, Alan Guth, Murray Gell-Mann, and Paul Gray. Peter Low spoke on behalf of his sisters Margaret and Julie, and the rest of the Low family. Please see the MIT News Office’s obituary, reprinted on page 24 of this journal.
Sara Seager

Associate Professor of Physics, Division of Astrophysics; and Ellen Swallow Richards
Associate Professor of Earth, Atmospheric and Planetary Sciences

Research Interests

Sara Seager’s current research interests are focused upon extrasolar planet atmospheres and interiors. Over 200 exoplanets are known to orbit nearby stars. Now that their existence is firmly established, a new era of exoplanet characterization has begun. A subset of exoplanets, called transiting planets, pass in front of and behind their stars, as seen from Earth. Transiting planets have immeasurably changed the field of exoplanets because their physical properties, including average density and atmospheric thermal emission, can be now be routinely measured. Seager’s group aims to understand the atmospheric composition and the interior structure of exoplanets, with a focus on the new and growing data set of transiting exoplanets.

Biographical Sketch

Sara Seager received her B.Sc. in mathematics and physics from the University of Toronto in 1994. She earned a Ph.D. in astronomy from Harvard University in 1999, where she investigated recombination in the early Universe before moving to the then brand-new field of exoplanets. Seager was a long-term member at the Institute for Advanced Study in Princeton, NJ, and a senior research staff member at the Carnegie Institution of Washington in Washington, D.C., before joining the MIT faculty in 2007. Seager was awarded the American Astronomical Society’s Helen B. Warner prize in 2007 for her work on extrasolar planet atmospheres.

For a list of Prof. Seager’s selected publications, please visit her faculty web page at web.mit.edu/physics/facultyandstaff/index.html.
Martin Zwierlein
Assistant Professor of Physics, Division of Atomic, Biological, Condensed Matter and Plasma Physics

Research Interests
Martin Zwierlein’s research focuses on ultracold quantum gases of atoms and molecules. Just a few billionths of a degree above absolute zero and a million times thinner than air, these gases provide ideal model systems for many-body physics in a clean and controllable environment.

After the realization of Bose-Einstein condensation (BEC) in dilute bosonic gases in 1995, the observation of superfluidity in Fermi gases became a long-standing goal in the field of ultracold atoms. Together with his colleagues at MIT, Zwierlein observed BEC of pairs of fermionic lithium atoms in 2003. With the help of Feshbach resonances, interactions between fermions could be tuned at will; this enabled Zwierlein to access the crossover from a BEC of molecules to a Bardeen-Cooper-Schrieffer (BCS) state of long-range pairs. Superfluidity was demonstrated in 2005 by setting the strongly interacting Fermi gas in rotation and observing an ordered lattice of quantized vortices. Scaled to the density of electrons in a metal, this form of superfluidity would occur already far above room temperature.

Zwierlein and colleagues moved on to address an old question on the ground state of imbalanced fermionic mixtures, wherein not every “spin up” fermion can find a “spin down” partner. At a critical spin imbalance—the Clogston-Chandrasekhar limit observed by Zwierlein—the superfluid state is destroyed and a strongly interacting Fermi mixture remains.

More recently, Zwierlein worked on an experiment on fermions and bosons in optical lattices at the University of Mainz. Fermi mixtures with repulsive interactions, confined to an optical lattice, might enable the simulation of an important model in the context of high-temperature superconductors, the fermionic Hubbard model.

Currently, Zwierlein is investigating ultracold mixtures of different fermionic species. An equal mixture of fermionic lithium-6 and potassium-40 atoms would constitute a fermionic superfluid in which the pairing partners are not related to each other by time-reversal symmetry. In their vibrational ground state, heteronuclear LiK molecules would possess a large electric dipole moment, opening up possibilities to study quantum gases with anisotropic long-range interactions.
Fermi mixtures involving more than one spin state per atomic species can serve as a rudimentary model system of exotic matter, such as quark (“color”) superfluids in the core of neutron stars.

**Biographical Sketch**

Martin Zwierlein studied physics at the University of Bonn and at the Ecole Normale Supérieure in Paris, where he received his undergraduate and master’s degrees in theoretical physics in 2002. Later that year, he started his Ph.D. in experimental atomic physics in the group of Wolfgang Ketterle at MIT. His research focused on the observation of superfluidity in ultracold fermionic gases, a model system for strongly interacting matter. After a postdoctoral stay at the University of Mainz in the group of Immanuel Bloch, Martin rejoined the MIT community as an assistant professor of physics in July 2007.

*For a list of Prof. Zwierlein’s selected publications, please visit his faculty web page at web.mit.edu/physics/facultyandstaff/index.html.*
Honors & Awards

Ulrich J. Becker, Professor of Physics, was named a Fellow of the American Physical Society.

Edmund Bertschinger, Professor of Physics and Physics Department Head, was awarded a 2007 Guggenheim Fellowship in consideration of his “distinguished achievement in the past and exceptional promise for future accomplishment.”

Hale Bradt, Professor of Physics Emeritus, received the Schola Mundus Est Award of the Gill St. Bernard’s School.

Min Chen, Professor of Physics, received the Distinguished Alumni Award of Tunghai University.

Bruno Coppi, Professor of Physics, was a Distinguished Citywide Lecturer of the University and City of Pavia, Italy.

Mildred S. Dresselhaus, Institute Professor and Professor of Physics and Electrical Engineering, was named a Foreign Fellow of the National Academy of Sciences, India; was awarded Honorary Doctorates at the Federal University of Ceara (Brazil), the University of Pennsylvania, and the University of Arkansas at Little Rock; and received the L’Oréal-UNESCO Award for Women in Science.

Peter Fisher, Professor of Physics and Division Head of Particle and Nuclear Experimental Physics, was named a Fellow of the American Physical Society.

Joseph Formaggio, Assistant Professor of Physics, was named an Outstanding Junior Investigator in Nuclear Physics by the U. S. Department of Energy; received the Reed Junior Faculty Award; and was awarded the Polansky Prize.

Anthony French, Professor of Physics Emeritus, was a co-recipient of the Excellence in Physics Education Award of the American Physical Society.
Thomas J. Greytak, Professor of Physics and Interim Department Head, was awarded the 2007 Dean’s Educational and Student Advising Award of the MIT School of Science; and named the Lester Wolfe Professor of Physics.

Eric W. Hudson, Assistant Professor and Class of 1958 Career Development Chair, received the Buechner Teaching Award of the MIT Physics Department.

Robert Hulsizer, Professor of Physics Emeritus, was a co-recipient of the Excellence in Physics Education Award of the American Physical Society.

Erich P. Ippen, Elihu Thomson Professor of Electrical Engineering and Professor of Physics, was awarded the 2006 Frederic Ives Medal of the Optical Society of America for “laying the foundations of ultrafast science and engineering, and providing vision and sustained leadership to the optics community.”

Roman Jackiw, Jerrold Zacharias Professor of Physics, was awarded the Closed-Timelike-Curves Prize of the University of London, Queen Mary College.

John King, Professor of Physics Emeritus, was a co-recipient of the Excellence in Physics Education Award of the American Physical Society.

Daniel Kleppner, Lester Wolfe Professor of Physics Emeritus, was awarded the 2006 National Medal of Science for “pioneering studies of the interaction between atoms and light, and for lucid explanations of physics to non-specialists”; received the 2007 Frederic Ives Medal of the Optical Society of America “for sustained innovation, discovery and leadership in the interaction of radiation with atoms and for his service and general educational activities”; and was elected to membership in the American Philosophical Society.

Nergis Mavalvala, Associate Professor of Physics and Cecil and Ida Green Career Development Professor, was awarded the John de Laeter Medal of the Australian Institute for Physics; and received the Harold E. Edgerton Faculty Achievement Award.

Gabriella Sciolla, Assistant Professor of Physics, received the Reed Award for Faculty.
Sara Seager, Associate Professor of Physics and Ellen Swallow Richards Associate Professor of Earth, Atmospheric and Planetary Sciences, was awarded the Helen B. Warner Prize of the American Astronomical Society.

Marin Soljačić, Assistant Professor of Physics, was named one of Technology Review's “Top 35 Innovators Under the Age of 35.”

Alexander van Oudenaarden, Keck Career Development Professor in Biomedical Engineering and Associate Professor of Physics, received the School of Science Prize for Excellence in Graduate Teaching.

Rainer Weiss, Professor of Physics Emeritus, was awarded the Gruber Cosmology Prize; and named a co-recipient of the Einstein Prize of the American Physical Society “for fundamental contributions to the development of gravitational wave detectors based on optical interferometry, leading to the successful operation of LIGO.”

Xiao-Gang Wen, Cecil and Ida Green Professor of Physics, was named a Distinguished Moore Scholar by the California Institute of Technology.

Promotions

Nergis Mavalvala to Associate Professor of Physics without tenure.

Günther Roland to Associate Professor of Physics with tenure.

Iain Stewart to Associate Professor of Physics without tenure.

Senthil Todadri to Associate Professor of Physics with tenure.

Vladan Vuletic to Lester Wolfe Associate Professor of Physics with tenure.
Physicist Francis E. Low, former MIT provost, dies at 85

Francis E. Low, a retired MIT physicist and provost who worked on the Manhattan Project, died of heart failure on February 16 at a retirement home in Haverford, PA. He was 85.

“Francis was a hero of the physics department,” said department head Marc Kastner. “His theoretical ideas shaped much of modern particle physics as well as condensed matter physics, and he was a wise, generous colleague who helped many of us when we were starting our careers at MIT.”

Low described his teaching and interactions with students as highlights in his long career. His former students include Alan Guth (PhD 1972), the Victor F. Weisskopf professor of physics at MIT; Mitchell Feigenbaum (PhD 1970), Toyota professor of mathematical physics, The Rockefeller University; and Susan Coppersmith (SB 1978), professor of physics, University of Wisconsin-Madison.

Low joined MIT’s physics department in 1957 and served as provost from 1980 to 1985. During that time, he encouraged a prominent role for the humanities in MIT’s curriculum. He was also proud that MIT became affiliated with the Whitehead Institute for Biomedical Research during his tenure as provost, according to his daughter, Margaret Low Smith.

Before becoming provost, he directed MIT’s Center for Theoretical Physics and the Laboratory for Nuclear Science. An Institute Professor, he retired from MIT in 1991 but continued to teach physics for a few more years.

In 1969, he became a founding member of the Union of Concerned Scientists. He served as chair for a short period but stepped down over a disagreement with members who refused to study whether nuclear reactors could be made safe and reliable.

During World War II, Low worked on the mathematics of uranium enrichment processes for the Manhattan Project at the Oak Ridge National Lab in Tennessee. He left the project to join the Army’s 10th Mountain Division in Europe. He served as a mule driver and later as an artillery surveyor.
After the war, Low went to Columbia University, where he earned his Ph.D. in physics in 1950, followed by postdoctoral work at the Institute for Advanced Study in Princeton, NJ. He spent a few years teaching at the University of Illinois at Urbana before arriving at MIT.

Low, who grew up in Manhattan, married his wife, Natalie Sadigur Low, in 1948. After she died in 2004, he moved from Belmont, MA, to Haverford.

He had a pilot’s license, enjoyed tennis, and was a gifted piano player, known among friends for his ability to sing and play tunes by Cole Porter.

In addition to his daughter Margaret, he is survived by another daughter, Julie; a son, Peter; and six grandsons.

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On Problem Solving

You can do it or you can just understand it.

If you’re very good at calculus, you could probably figure out a way of doing it without thinking.

You solve the electromagnetic wave problem one way or another — generally badly.

It’s not hard because we’re only going to do things we can do.

If it works, it’s probably right.

On Teaching Technique

I’m lying to you a little, but it’s OK.

And if I’m feeling sadistic, I may assign it as a problem.

I’m just mentioning it so you know I know about it.

You can count on it, but don’t rely on it.

It’s a good question, but I think it’s not meaningful.

It’s a little bit silly to describe uncertainties too exactly.

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Excerpted from “Francis E. Low: Coming of Age as a Physicist in Postwar America,” by David Kaiser, physics@mit, Fall 2001. The complete article is available in PDF at web.mit.edu/physics/alumniandfriends/physicsatmit/fall2001.html.
2007 Barrett Prize

Tucker A. Jones SB ’07

Thesis advisors: Saul Rappaport, Alan Levine

The award, established by students, friends, relatives, and colleagues of the late Prof. Alan Barrett, honors his outstanding influence in the education of physicists and his fundamental contributions to the science and technology of astrophysics. A $1,000 prize is awarded annually to a senior undergraduate or graduate student in Astrophysics.

2007 Malcolm Cotton Brown Award

Ming Yi SB ’07

Thesis advisor: Eric Hudson

Awarded to a senior of high academic standing in physics who plans to pursue graduate study in experimental physics. Given in memory of Lt. Malcolm Cotton Brown, Royal Air Force, who was killed in service on July 23, 1918. The fund currently provides a prize of $1,000.

All photos Graham Gordon Ramsay
The Burchard Scholars Program brings together distinguished members of the faculty and promising sophomores and juniors who have demonstrated excellence in some aspect of the humanities, arts, and social sciences, as well as in science and engineering. The Burchard Program format is a series of dinner-seminars held during the academic year to discuss topics of current research introduced by MIT faculty members. The Program is sponsored by the Dean’s Office, School of Humanities, Arts, and Social Sciences.

2007 Philip Morse Memorial Award

Tongyan Lin SB ’07

Awarded to a senior of high academic standing in physics who plans to pursue graduate study in physics. Given in memory of Philip Morse, MIT Professor of Physics, one of the renowned physicists of the 20th century, whose contributions spanned from basic physics to engineering. The fund currently provides a prize of $1,000.
The Joel Matthew Orloff Awards were established by Dr. and Mrs. Daniel Orloff in memory of their son Joel, a physics major, who died in an automobile accident shortly after graduation from MIT in 1978. One thousand dollars is awarded to each of several physics majors in the following three categories:

**Scholarship**—given to the student with either the highest GPA in physics courses or, if a tie, the highest overall GPA.

**Research**—given to the student with the most outstanding senior thesis.

**Service**—given to the student with the most outstanding service to the Department, Institute, or community.

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2007 Joel Matthew Orloff Awards
Scholarship
Widagdo Setiawan SB ’07
    Thesis advisor: Wolfgang Ketterle

Research
Anna K. Labno SB ’07
    Thesis advisor: Matthew Lang

Service
Zachary Wissner-Gross SB ’07
    Thesis advisor: Young S. Lee

The Joel Matthew Orloff Awards were established by Dr. and Mrs. Daniel Orloff in memory of their son Joel, a physics major, who died in an automobile accident shortly after graduation from MIT in 1978. One thousand dollars is awarded to each of several physics majors in the following three categories:

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**Research**—given to the student with the most outstanding senior thesis.

**Service**—given to the student with the most outstanding service to the Department, Institute, or community.
2007 Sigma Pi Sigma inductees.

2007 Sigma Pi Sigma Inductees

Timothy G. Abbott
Jacob G. Bernstein
Daniel B. Chonde
Jennifer T. Choy
Yiwen Chu
Adam Vy Donovan

Chintan Hossain
Daniel M. Kane
Isaac H. Kim
John J. Lee
Samuel Lee
Tongyan Lin

Robert Matthew Panas
Yuri A. Podpaly
Earl Taylor Roan
Widagdo Setiawan
Ryan Sheffler
Kevin Takao Takasaki

Nicholas Day Walrath
Zachary Wissner-Gross
Ming Yi

2007 Phi Beta Kappa Inductees

Timothy G. Abbott
Jacob G. Bernstein
Daniel B. Chonde
Jennifer T. Choy
Yiwen Chu
Adam Vy Donovan

Robert Matthew Panas
Yuri A. Podpaly
Earl Taylor Roan
Widagdo Setiawan
Kevin Takao Takasaki

Nicholas Day Walrath
Zachary Wissner-Gross
Ming Yi

2007 Phi Beta Kappa inductees.
Other Undergraduate Awards & Honors

Zachary Wissner-Gross (SB ‘07) was awarded the Fannie and John Hertz Foundation Fellowship, the National Defense Science and Engineering Graduate Fellowship, and the National Science Foundation Graduate Research Fellowship. He was also elected to the Xi Chapter of the Phi Beta Kappa Honor Society, and awarded Second Prize in the Prize for Writing Science Fiction of MIT’s Program in Writing and Humanistic Studies.

The following graduate award recipients for the 2005-06 academic year were announced in September 2006.

2006 Martin Deutsch Student Award
For Excellence in Experimental Physics

Gretchen Campbell  Atomic Physics
Thesis advisors: Wolfgang Ketterle, David Pritchard
Awarded to a graduate student in the mid-course of research for study in any area of physics, with preference given to experimental physics. The award was created in honor of Prof. Martin Deutsch’s outstanding contributions to Nuclear Physics as an educator and researcher and currently carries a prize of $1,000.

2006 Andrew M. Lockett III Memorial Fund Award

Jessie Shelton  String Theory
Thesis advisor: Washington Taylor
Awarded to a graduate student in theoretical physics, with preference given to students from Los Alamos, NM, and New Orleans, LA. The award currently carries a prize of $1,000. The award was established by Mrs. Lucille Lockett Stone in memory of her husband, Dr. Andrew M. Lockett, who received his Ph.D. in physics from MIT in 1954.
2006 Buechner Teaching Prize

**Oliver Dial**  Experimental Condensed Matter Physics

Thesis advisor: Raymond Ashoori

Awarded to a graduate student for outstanding contributions to the educational program of the Department during the past academic year. The $1,000 prize was established in 1987 by the late Mrs. Christina Buechner in memory of her husband Prof. William Buechner, who served as Physics department head from 1962-67.

Other Graduate Honors & Awards

**Georgios Choudalakis** (Experimental High Energy Physics. Thesis advisor: Bruce Knuteson) was awarded the 2007 George and Marie Vergottis Fellowship.

**Jacob Hartman** (Astrophysics. Thesis advisor: Deepto Chakrabarty) received the 2007 Edward L. Horton Fellowship Award. The award, established by the MIT Graduate Student Council, recognizes the contribution of any student or student group that “fosters fellowship within the graduate student community” at MIT.
How big is the observable universe?
What is it made of?
Why does space repel itself?
In January 2006—the middle of summer in the Southern hemisphere—a bus full of MIT alumni, family, and friends ascended a narrow, winding dirt road through the coastal range of Chile up to 2400 meters (8000 feet) elevation. After visiting European and American national observatory sites during the preceding days, the group was eager to see the private observatory of which MIT is a partner: the Magellan Telescopes at Las Campanas Observatory. Only one traveler in the group had been there before: five years earlier, Jane Pappalardo had attended the dedication of the newly built telescopes. The author, serving as a scientific tour guide, was excited to arrive finally at the facility his colleague, MIT Magellan director Prof. Paul Schechter, had helped design and commission. After traveling a week through Northern Chile we had reached the summit of a remarkable trip.

Chile—a thin strip of land—between the Pacific Ocean and the crest of the Andes—is an astronomical mecca. The cold Humboldt ocean current flowing northward from Antarctica keeps the marine clouds low against the wall of coastal mountains. To the east, the Andes are high enough to block most of the...
moisture from the Amazon rain forest. As a result, northern Chile is home to the driest desert in the world—the Atacama—and has the clearest readily accessible skies. Chile takes advantage of this natural resource to host several international astronomical observatories in exchange for a 10% share of observing time on the telescopes. It is also beginning to host a small but growing trade of astro-tourism. Our tour, organized by the MIT Alumni Travel Program, was called “The Skies of the Southern Hemisphere: Chile & the Magellan Project.”

The Magellan Project is operated by a consortium of private universities (Harvard, MIT, Michigan, and the University of Arizona) plus the Carnegie Institution of Washington. The consortium built and operates the Magellan Telescopes that produce, without adaptive optics correction, among the best optical images on earth. (The Hubble Space Telescope does better above the atmosphere.) After viewing two days earlier the lavish facilities at the European Paranal Observatory (including an astronomers’ “dormitory” with an indoor swimming pool), the MIT travelers were eager to see the facilities of the “lean and mean” Magellan Project.

At the observatory we were warmly greeted by Magellan Site Manager Frank Perez, who showed us the telescopes, as well as the mirror resurfacing facility (where the mirrors are cleaned and a thin film of aluminum is reapplied every two years), and some of the complex instruments that analyze the light collected by
the big telescopes. (The last time an eyepiece was put on one of the big telescopes was during the dedication ceremony.) Frank explained how the electronic guider sensed gradual changes in the mirror shape during observations and automatically applied forces to keep the mirror in the right shape, using the technology developed by Prof. Paul Schechter.

Time Machines
As impressive as modern telescopes are for their high technology, it is their scientific output that most excites astronomers. At Magellan we were fortunate to be met by MIT astronomer Rob Simcoe, then a Pappalardo Postdoctoral Fellow and now an Assistant Professor of Physics at MIT, who showed the group his chemical analysis of gas clouds tens of billions of light years from Earth. How could he see so far, and what do his results teach us? [Author’s note: a challenge to challenge to the reader: explain how light can travel more than 40 billion light years in a time of less than 13.7 billion years, the age of our observable universe. The answer will be given at the end of this article.]

Telescopes are time machines. It takes light eight minutes to travel to us from the sun, four years to reach us from the next nearest star, and more than ten billion years to arrive from the quasars observed by Dr. Simcoe. A quasar is a tremendously
bright light source existing in the centers of some distant galaxies. A quasar’s power comes from the gravitational potential energy released as gas spirals into a giant black hole. While quasars are intrinsically fascinating objects, they are also a powerful tool for chemical analysis of gas within or between other galaxies anywhere along the line of sight to the quasar.

Hydrogen, carbon, and other chemical elements absorb light of distinct frequencies as it moves from the source to us, creating narrow dark regions in the quasar spectrum. The wavelengths of these dark regions are shifted by the expansion of the universe in such a way that astronomers can determine where and when the quasar light was absorbed. Using the Magellan Telescopes, Dr. Simcoe measured the rate of increase of carbon in the universe as it was produced in stars which pollute their surroundings. He found that the cosmological buildup of carbon was gradual over the last ten billion years and rapid before then. Would that the same were true for carbon in the Earth’s atmosphere!

**Comet of a Lifetime**

The success of our first alumni tour to Chile, in 2006, inspired its imitation by several other universities including Yale, whose travel brochure featured the photography of MIT alumus and Physics Visiting Committee member Bob Johnson. Of course we had to return to Chile to do better than the competition. One year later, our timing couldn’t have been better. The second MIT alumni tour of the Southern skies arrived in the Atacama Desert just after Comet C/2006 P1 McNaught passed closest to the sun in mid-January 2007. We first spotted the...
Two Short Lectures on Astrophysics by Dr. Edmund Bertschinger

Visits to the natural and archaeological wonders of the Atacama during the alumni trip were interspersed with my lectures on astrophysics, which were enjoyed with pisco sours. I am a theoretical astrophysicist; most of my research conducted in the MIT Kavli Institute for Astrophysics and Space Research has focused on trying to understand what 96% of the universe is made of and how it behaves. Atoms and their constituents comprise only 4% of the universe today!

**Dark Matter**

Dark matter is the nondescript name given to the diffuse material providing most of the mass of galaxies and playing a key role in galaxy formation. Its existence—deduced from the absence of sufficient mass contained in visible stars and gas to keep galaxies in their observed orbits—was first proposed in the 1930s. The successful prediction of new matter from its unseen gravity is not unprecedented; in the 1840s the eighth planet, Neptune, was deduced and then found from irregularities in the orbit of Uranus.

The irregularities in galactic orbits produced by dark matter are far more dramatic than the minor perturbations in the solar system. Our galaxy, the local group of galaxies, and all galaxy clusters would fly apart—indeed, they would not even have been assembled after the big bang—without far more gravitating mass than is seen. Unlike Neptune, though, the cosmic dark matter has not yet been seen by any measurements except the effects of its gravity. However, a panoply of indirect arguments show conclusively that the dark matter cannot be made of atoms or known particles. The most plausible explanation for dark matter is a new elementary particle generically called a “weakly interacting massive particle” or WIMP. WIMPs are being searched for by the very rare collisions they have with atoms in terrestrial laboratories, including those of MIT physics faculty Enecali Figueroa-Feliciano and Peter Fisher and Pappalardo Fellow Jocelyn Monroe.

The properties of galaxies like our own Milky Way give us important clues to the nature of dark matter, since galaxies formed as a result of gravitational condensation out of the expanding remnants of the big bang and most of the gravitating mass is dark matter. (Dark energy, as we shall see, is very different and plays little role, if any, in galaxy formation.) Despite the complexity of galaxy formation and evolution, the observed properties of galaxies point to several firm conclusions about dark matter. In particular, dark matter particles must be so small (as measured by their cross sections for elastic and inelastic collisions) as to be nearly collisionless. A cloud of dark matter particles would easily pass through the earth, the sun, or another dark matter cloud. Colliding atomic gas clouds, by contrast, are shock heated and cool by emission of photons. Add gravity, and the result of heat loss to photons is to compress to higher density, concentrating atoms into dense objects—stars and planets—while dark matter remains diffuse. The average density of dark matter in the universe today is about 2 milligrams in a volume equal to that of Earth. The local value in our galaxy is approximately one million times higher, still a better vacuum than interplanetary space.

Approximate composition of the universe today, by fraction of mass-energy of the total. Neutrinos, photons, and other known particles contribute less than 1%. “Dark” means “unseen by all measurements except gravity.” Dark energy and dark matter have different gravitational effects. (Image credit: NASA/WMAP Science Team)
The very existence of galaxies implies that the clouds of dark matter particles which seeded galaxy formation must have been very cold, otherwise thermal motions of the particles would have dispersed the clouds before galaxies could form. This realization led to the exclusion of neutrinos as dark matter in the 1980s: neutrinos born in the fires of the big bang are too “hot” to allow galaxy formation if they were the dark matter. The most popular candidate for dark matter today is a hypothetical “cold” WIMP called the neutralino. Like the neutrino, the neutralino rarely collides with anything. However, the neutralino, if it exists, must be much heavier than the neutrino, hence its temperature decreases much faster with cosmic expansion. If the neutralino weighs one hundred times as much as a proton (a plausible value), then the dark matter in intergalactic space today is predicted to have a temperature of about 20 picokelvin, more than 20 times colder than the temperatures reached in the Bose-Einstein condensates created by Prof. Wolfgang Ketterle.

My own studies of dark matter aim at a detailed theoretical understanding of dynamics starting from the early universe and going forward in time until galaxies form. Interestingly, the hardest questions involve the simplest physics: Newton’s laws of motion and the inverse square law of gravity. A self-gravitating gas of cold dark matter particles develops turbulence owing to the nonlinear interaction of structures of many different sizes. This turbulence is more complicated than the wake of an airplane or boat because, unlike an ordinary fluid, dark matter is collisionless.

Most research on galaxy formation use large numerical simulations, while my research emphasizes the complementary approach of analytical techniques solving mathematical equations. One result is a prediction that the dark matter should exhibit very high density surfaces, called caustics, which are a three-dimensional analogue of the bright lines of light seen on the bottom of a swimming pool. These caustics—as well as the small dark matter clouds predicted to rain onto galaxies—would have little effect on galactic structure but they might affect experimental searches for dark matter particles or their annihilation products. Conversely, detection of dark matter may one day test our models of collisionless turbulence.

**Dark Energy**

Four percent of our universe is atoms, which make up everything we are and can see; twenty-two percent is dark matter. The remaining 74% is dark energy. Dark energy is the name given to attempts to explain a stunning discovery announced in 1998 by two teams of astronomers. Instead of slowing down from the gravitational attraction of everything to everything else, the expansion of the universe is accelerating. It’s as if one were to toss a ball up in the air and gravity, instead of pulling it back to earth, pushes it ever faster and further into deep space. Apparently, if you could take a ball out to a distance of a few hundred million light years, this is exactly what would happen!

Statistically, the strongest evidence for dark energy comes from measurements of cosmic expansion inferred from supernova explosions seen across the visible universe. Measurements of distance and redshift (the amount by which the universe has expanded since the light was emitted) can be combined to give the expansion history of the universe, and therefore measure whether the expansion is accelerating or decelerating. The so-called Type Ia supernova provides the standard signal by which distance is indirectly measured: a carbon-oxygen white dwarf star—the cold, dead remains of a star somewhat more massive than our sun—slowly steals mass from a binary companion until the white dwarf exceeds the maximum stable mass worked out by Chandrasekhar in the 1930s, leading to a huge supernova explosion which emits a flash of light similar in size for all Type Ia supernovae. By combining the calibrated optical emission of these explosions with their brightness observed on Earth, astronomers can infer the distance. Years of intense scrutiny have only strengthened the conclusions drawn a decade ago: Type Ia supernovae tell us that something is causing the universe to accelerate. Almost all we “know” about this something is the name cosmologists have given it: dark energy.

Despite their names, dark energy and dark matter have, we think, only two things in common. First, the only evidence for their existence comes to date from their gravitational effects. Second, the evidence for both is so strong, and involves such an interlocking web of different measurements, that the simplest hypothesis consistent with the data is that both dark substances exist. Of the two, dark energy is harder to study because it appears to play no role in galaxy formation, nor
does it concentrate in galaxies. Something causes distant galaxies to repel each other while nearby ones attract. Dark energy behaves like a virus that has taken over the cellular machinery of space, forcing it to grow without limit.

In what sense can one call dark energy a substance? Dark energy might be a gravitating substance, albeit with a repulsive rather than attractive force. Paradoxically, empty space itself—a vacuum—may be the answer to the dark energy puzzle. According to quantum physics, the vacuum is an active environment full of “virtual” particles and antiparticles that materialize and live briefly on time borrowed from the Heisenberg Uncertainty Principle before disappearing again. While not a substance one can hold in one’s hand, this sea of fluctuating virtual particles causes gravity. (Light also causes gravity and is difficult to hold in one’s hand.) In the 1960s it was realized that vacuum quantum fluctuations correspond to a substance with positive energy and negative pressure, and that negative pressure causes repulsive gravity accord-

ing to general relativity. The effect is the same as the repulsive gravity term Einstein introduced in 1917, when he realized that his field equations would not permit the universe to be static in the presence of ordinary matter, as he then thought it was. Einstein’s cosmological constant was, by assumption, just strong enough to counteract the mutual gravitational attraction of matter. Today’s dark energy is several times stronger. Einstein’s self-described greatest blunder—the cosmological constant—may yet be correct, if made a little stronger.

Unfortunately, theoretical estimates of the vacuum energy show that, unless some extraordinary cancellation occurs, dark energy should be up to 123 orders of magnitude, that is $10^{123}$ times, as strong as is observed. This “cosmological constant problem” remains a great challenge to physicists.

Instead of vacuum energy, dark energy might be an exotic form of mass-energy called a slowly rolling scalar field. This idea has traction: the same mechanism was invoked by Professor Alan Guth to drive a phase of accelerating expansion in the very early universe. His inflationary universe model resolves many of the puzzles of the big bang theory, especially those related to the large-scale uniformity of the visible universe and the small fluctuations that give birth to galaxies. However, it seems bizarre that the universe would begin another phase of inflation around the time our sun was born. That is very late in the universe by the standards of particle physics.

A third possibility is that dark energy is not a substance at all, but instead arises due to modifications of Einstein’s theory of general relativity. This possibility is subtle because the measurements of dark energy made to date assume that general relativity is exact. I’ve been studying ways to test modified gravity theories that add one free parameter to general relativity. The approach is similar to what has been done to test general relativity in the solar system. By combining various measurements of light as well as motions of galaxies, it should be possible to determine whether dark energy is a substance or modified gravity. Understanding dark energy is a major goal of cosmology research for the next decade—if not the next century!
comet just above the horizon about 45 minutes after sunset on our first evening in the Atacama Desert. With spotting scope, binoculars, and averted vision we saw a thrilling tail. For several travelers, it was their first comet. For all of us it was the best.

Comet McNaught came from the Oort cloud of comets far beyond Neptune (not to mention beyond the dwarf planets like Pluto), on an orbit nearly at right angles to the plane of Earth’s orbit. After passing the sun it was visible only in the southern hemisphere. I cautiously opined to the group that McNaught should be visible for several more days and might appear brighter as it moved farther from the sun and was visible longer after sunset. However, nothing prepared us for the incredible tail shown in Figure 1. Several of us saw a view like this (albeit after the comet nucleus had set) from the amateur Collowara Observatory in the mountains above La Serena.

A bright early evening comet is every amateur astronomer’s dream. At the end of a fabulous dinner in Calama, I told the group that we had prepared a special treat after dessert. Armed with sweaters and binoculars, we convened onto the hotel steps to watch the awesome harbinger of an unforgettable trip. When I exclaimed excitedly, “This is the comet of a lifetime!” one of the group members replied, “Comet? This is the trip of a lifetime!”

The nighttime sky in Chile even without, but especially with, a bright comet, is breathtaking. In one viewing that evening, we saw a comet or planets ten light minutes distant, the nearest star outside our solar system some five orders of magnitude (one hundred thousand times) further away (Alpha Centauri, four light years), and the nearest galaxies, approximately another five orders of magnitude beyond (the Magellanic Clouds). One more step with this multiplier covers the entire observable universe!

Continued from page 36
But it isn’t enough to see the pictures—I stood silently beneath a star-spangled wide-open sky to soak in the grandeur of the cosmos. I felt in my heart the neutrinos coming from distant supernovae, like those measured on the earth 20 years ago when Supernova 1987A blazed in the Large Magellanic Cloud. I waved at the nearby stars Beta Pictoris and Epsilon Eridani, whose orbiting disks of dusty debris almost certainly harbor young planets. Somewhere, perhaps, others were waving back at us. Sharing this elation of the skies with alumni, their family, and friends is one of the greatest pleasures of my life.

**MIT Alumni and the Spice of Life**

Each of the two MIT alumni tours to Chile included an optional extension. In 2006, the first group visited the southern lakes region of Chile, a lush area of Chile reminiscent of Bavaria. In 2007 the second group visited Easter Island, an archaeological treasure in the middle of the Pacific Ocean. Having read Jared Diamond’s *Collapse* before the trip, I found the famous stone statues haunting, and the metaphor for the fragility of the Earth’s ecosystem unsettling.

MIT alumni are remarkable and delightful. In 2006, when our bus driver got lost driving to Paranal Observatory, Howard Messing pulled out his handheld GPS receiver, Bob Johnson pulled out a good map, and together we charted the correct route. The 2006 alumni group also suggested a tour of the Large Hadron Collider at CERN, the European laboratory for particle physics in Geneva, Switzerland. Institute Professor Emeritus Jerry Friedman led a special tour of this laboratory in May 2007, showing the alumni the enormous particle detectors which soon will

![Figure 7](image-url)
be sealed up to measure the highest-energy collisions of protons and ions produced on earth.

For the 2007 trip, alumna Nancy Pottish invited her friend and postgraduate employer Bob Jones, who was a senior engineer at Perkin-Elmer during the construction of the Hubble Space Telescope. Bob gave us a personal account of the infamous “spherical aberration” error in the polishing of the Hubble mirror when two employees tried to outsmart the system. His guest lecture and slideshow were a wonderful addition to our program.

One of the greatest thrills of traveling with an MIT alumni group is the likelihood that whatever we do, the group will have expertise. In the Atacama Desert, Paul Todd taught us about extremophiles—life such as sulfur-eating bacteria living in the El Tatio Geysers—and their interest as a possible form of life on Mars. Geophysicists Dave Hadley and Bob Hart taught us about rift and subduction zones and their importance for the Andes. But the sciences are only part of our interest and expertise. Throughout Chile the group’s birders shared their binoculars, field guides, and excitement with everyone. At the Cousino Palace in Santiago, Ali Moiin taught the Chilean tour director about the lavish Persian carpets as the rest of the group listened in delight.

Alumni trips also remind us how respected MIT is around the world. The Director of Conservation at the Precolombian Art Museum in Santiago proudly described her collaboration with MIT Materials Science Professor Heather Lechtman, studying the metallurgy of ancient bronze artifacts. Observatory directors spent hours with us and expressed pride in the role MIT played in their facilities.

The 2007 group asked me how I would top their experience for the next trip: Would I, for example, order up a supernova in our galaxy? I ducked that question but the answer is straightforward: MIT alumni will make the trip fascinating, original, and fun. However, for variety we are making one change to the pattern: the next trip to Chile will be in the austral winter, July 21-August 1, 2008 (including an optional extension to Easter Island). Instead of the Magellanic Clouds, we’ll see the magnificent center of our own galaxy overhead. This will increase the chances for a bright supernova!

For information and reservations see alum.mit.edu/lt/travel/calendar/. A travelogue of the Chile trip is online at web.mit.edu/edbert/Chile/. Also watch for future trips to view total solar eclipses in some beautiful places; if anything can top the comet of a lifetime, it’s a total solar eclipse!

Postscript: How Far We Can See

Returning to the author’s challenge question from “Time Machine” on page 35: How can light travel more than 40 billion light years in only 13.7 billion light years? The answer: by surfing on expanding space.

To understand this, follow a light ray backwards in time and outwards in space from the Milky Way to a distant quasar. For simplicity, assume that the expansion of the universe stretches galaxies apart in proportion to the time since the big bang. Divide up the timeline into ten equal parts, each of 1.37 billion light years dura-
tion. Approximate the expansion of the universe as a series of steps: the galaxies begin crushed into a tiny volume, then they are separated by 10% of their present distances, next they are separated by 20% of their present distances, and so on.

During the first increment along the trip backwards in time the light traveled a distance of 1.37 billion light years and, in our approximation, the galaxies remained at their present-day separations.

During the second increment the light traveled another 1.37 billion light years; however, the galaxies were 10% closer to each other then. Consequently, during this interval the light traveled between galaxies which today are separated by 1.37/0.90=1.52 billion light years. Similarly, during the third increment light traveled between galaxies which today are separated by 1.37/0.80=1.71 billion light years. Repeating the process for a total of 13.7 billion years gives a total distance traveled in billions of light years, as measured by today's galaxy positions, of

\[
\left(1.0 \times \frac{1.0}{0.9} + \frac{1.0}{0.8} + \frac{1.0}{0.7} + \frac{1.0}{0.6} + \frac{1.0}{0.5} + \frac{1.0}{0.4} + \frac{1.0}{0.3} + \frac{1.0}{0.2} + \frac{1.0}{0.1}\right) \times 1.37 \approx 40.1 \text{ (billion light years)}
\]

This estimate can be refined by using calculus and a more accurate expansion history; the actual result is uncertain, but is almost certainly larger than 40 billion light years.

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**Dr. Edmund Bertschinger** is a Professor of Physics, former Division Head of Astrophysics, and, as of January 1, 2008, Department Head of Physics at MIT. He is a theoretical astrophysicist whose research interests focus on cosmology and relativistic astrophysics. A native of California, he received his B.S. in Physics from Caltech in 1979 and his Ph.D. in Astrophysical Sciences from Princeton University in 1984. Following postdoctoral positions at the University of Virginia and at UC-Berkeley, he joined the MIT faculty in 1986, where he rose through the ranks, reaching his present position as full professor in 1996.

Professor Bertschinger is passionate about education. He enjoys teaching classical mechanics, electromagnetism, quantum mechanics, relativity, and cosmology. In collaboration with Dr. Edwin Taylor, he introduced an undergraduate class on black holes and astrophysics that is taken by MIT alumni as well as by undergraduates. In 2002, he received the Physics Department's Buechner Teaching Prize for his undergraduate and graduate classes in relativity.

Professor Bertschinger also loves working with students on research in astrophysics, cosmology, and general relativity. His research students at the high school and undergraduate level have won national prizes for their work, including First Prize in the Intel Science Talent Search. His former Ph.D. students now hold faculty positions at Harvard, Columbia, UC-Berkeley, and other fine universities.

As a member of the MIT Kavli Institute for Astrophysics and Space Research, Prof. Bertschinger leads a research program studying the mysteries of dark energy and dark matter. He and his research students investigate the formation of cosmic structure after the big bang, the physics of dark matter both in the early universe and in forming galaxies, and the physical processes governing matter and radiation close to black holes.
IT and the scientific community lost a giant in 2002, when Victor Frederick Weisskopf passed away. Known by students and colleagues alike as “Viki,” he was among the most accomplished and admired physicists of the twentieth century. A beloved teacher, Weisskopf developed a sought-after style that emphasized conceptual understanding and qualitative description over rigorous mathematical derivation. He used to sum up his style by the slogan, “search for simplicity.”

I was lucky enough to witness Viki’s great powers up close during his later years. He ventured from MIT to Dartmouth College (where I was a student) during the early 1990s to give a physics department colloquium, and I sat glued to my seat along with my fellow physics undergraduates. To this day I remember Viki’s masterful performance: with the barest of algebra and no calculus in sight, he demonstrated why mountain peaks rarely rise higher than 10 kilometers; why water droplets from a leaky ceiling tend to form with radii of around a centimeter; and why the surface of a lake will retain its mirror-like smoothness until winds pick up above a speed of twenty centimeters per second. Each of these effects that Weisskopf displayed for us could be derived from the trade-offs between gravity and
surface tension. The numbers ultimately derived from simple properties of atoms and molecules—properties well within the grasp of undergraduates. We were mesmerized. Only later did I learn that Viki had published many of these insights in a monthly column, “Search for Simplicity,” that appeared in the *American Journal of Physics* during 1985 and 1986.

After Weisskopf’s colloquium, some students joined him for dinner. He and I got to talking—my interests in the history of science had already begun to take form, alongside my interests in physics—and he graciously continued our discussion by letter over the next few years. To those who did not know Viki, he and I might appear unlikely pen-pals: a world-renowned physicist and scientific statesman trading letters with an overeager undergraduate. But to the many physicists and students who benefited from Weisskopf’s tutelage over the years, such interactions would have seemed typical. Years later, when I was asked to write an entry on Weisskopf for the updated *Dictionary of Scientific Biography*, I leaped at the chance to delve more deeply into Viki’s life and work. Here are some of the things I learned.

**A Physicist’s Grand Tour**

Weisskopf was born into a cultured, upper-middle-class family of assimilated Jews in Vienna. His father Emil, originally from Czechoslovakia, was trained in law. His mother Martha hailed from one of the leading families of fin-de-siècle Vienna. They instilled in Viki and his siblings—an older brother named Walter and a younger sister named Edith—a strong appreciation for music and the arts, often taking the children to concerts, plays, and museums. Viki began studying music at an early age, and quickly developed into an accomplished pianist; he performed chamber music with friends and colleagues throughout his life. His family also supported his budding interest in socialism and political activism. He joined a socialist student group in high school, worked with the
Social Democratic Party, and took part in the general progressive movement often dubbed “Red Vienna,” which aimed to improve education and housing for workers.

From his earliest days, Weisskopf also harbored a deep interest in science and nature. As a fifteen-year-old, he conducted a detailed astronomical study with a boyhood friend, staying up all night to catalog the shooting stars during the peak of the annual Perseid meteor showers. Their work appeared in the leading astronomical journal, *Astronomische Nachrichten* (Astronomical Notices), in 1924. He followed upon this success with avid studies of physics at the University of Vienna, where he quickly impressed physicist Hans Thirring. Thirring encouraged young Viki to continue his education beyond the confines of Austria. And so, at the age of twenty, Weisskopf moved to Göttingen, Germany, to study with the great Max Born. He completed his Ph.D. under Born’s direction in 1931, working on the application of quantum theory to the breadth of spectral lines, the thin beams of light emitted by atoms when excited by an outside source of energy.

Next came a string of postdoctoral fellowships. Weisskopf hit every major stop along the way, studying with all the principal inventors of the new theory of quantum mechanics, physicists’ description of matter and forces at the atomic scale. These leaders had only just finished cobbbling together quantum mechanics—rife with bizarre departures from ordinary experience—during the mid-1920s, a few years before Weisskopf embarked on his postdoctoral tour. The new material, and the enduring sense that physics had undergone a major revolution, was still fresh.

Weisskopf’s first destination was Leipzig to study with Werner Heisenberg (fall 1931), before moving to Berlin to work with Erwin Schrödinger (spring...
A Rockefeller Foundation Fellowship allowed Weisskopf to spend the 1932–33 academic year studying with Niels Bohr in Copenhagen and Paul Dirac in Cambridge, England. Wolfgang Pauli hired Weisskopf as his assistant in Zurich beginning in autumn 1933, where he remained until the spring of 1936. Then it was back to Copenhagen for more work with Bohr. The novelist Henry James could scarcely have invented a more spectacular “grand tour” for a young physicist of Weisskopf’s generation (Figure 2). During his first stay in Copenhagen, Viki met and fell in love with a young Danish woman, Ellen Tvede. They married in 1934, and spent the next fifty-five years together, until her death in 1989.

Quantum Electrodynamics

Weisskopf had been surprised when Pauli offered him the assistantship position in 1933; Viki always harbored a certain lack of self-confidence when it came to his work. This was hardly helped when he arrived in Zurich and the imposing, acerbic Pauli asked who he was. Flummoxed, Weisskopf stammered something about the job offer. Pauli looked up from his desk and explained that he had really wanted to hire Hans Bethe, but Bethe’s interests had already shifted to solid-state physics (a topic Pauli famously dismissed as “squalid-state” physics), and so Weisskopf would have to do.

Despite the inauspicious beginning, Weisskopf’s stay in Zurich proved to be remarkably productive. With Pauli, he delved into quantum electrodynamics (QED), a topic recently spearheaded by Pauli, Heisenberg, Dirac, and others. The goal was to describe electromagnetic phenomena—the motion of charged particles, the behavior of electric and magnetic fields—in a manner consistent with the still-new quantum mechanics. Only a few years old, the subject was already mired in difficulties; Weisskopf would soon produce several major breakthroughs.

In Dirac’s earliest efforts with QED in the late 1920s and early 1930s, he had found unexpected solutions to his equations. Though baffling at first, in time physicists came to interpret these solutions to mean that every type of ordinary particle has an antimatter cousin carrying the same mass but opposite electric charge. Electrons, for example, should have companion particles (dubbed “positrons”) that each carry one unit of positive electric charge. His explanation remained quite controversial, even after the first experimental evidence for positrons was found in 1932.

Further conceptual problems marred QED. As the early architects of QED had found to their dismay, straightforward application of their new equations yielded nonsensical results. Whenever they posed simple questions, such as the probability for two electrons to scatter, their formalism returned “infinity” rather than some finite number. Electrons might have a high probability to scatter (say, 75%), or a low one (10%), but whatever it was, it simply couldn’t be
infinite! Yet try as they might, none of these physicists had found any way to complete meaningful calculations in QED.

Weisskopf re-analyzed one of these stubborn calculations, regarding how an electron would interact with its own electric field. Charged objects serve as the source for electric and magnetic fields; and their behavior is affected, in turn, by the presence of electric and magnetic fields. So how would an electron behave in its own self-field? The problem seemed intractable because the strength of an object’s electric field grows the closer one approaches that object. This is rarely a problem for macroscopic objects, which always have some finite spatial extension. But physicists believed that electrons were point-like objects, with virtually no spatial extension at all. Indeed, the first attempts to calculate an electron’s self-energy found it to diverge—that is, blow up to infinity—as $\frac{1}{r^2}$, where $r_e$ was the radius of the electron. A point particle, with $r_e = 0$, would have an infinite self-energy.

These early calculations had ignored possible effects from the still-controversial positrons. By the time Weisskopf took up the problem, however, early evidence seemed to indicate that positrons might really exist after all. He reworked the self-energy calculation, taking into account the behavior of both electrons and positrons. Weisskopf’s calculation (with a little help from Wendell Furry, one of Oppenheimer’s postdocs, who’d corrected Viki’s sign error) showed a much more gradual breakdown of the equations than anyone had found previously: the electron’s self-energy diverged as the logarithm of the electron radius. Such a function would still become infinite in the limit of a genuine point particle (with $r_e = 0$), but this gentle divergence seemed far less threatening to the entire QED edifice than the earlier results. Indeed, Weisskopf’s revised calculation, published in 1934, gave many physicists hope that the problems of QED might be conquered after all.

That same year, Weisskopf teamed up with Pauli to scrutinize the behavior of antiparticles. They showed that even charged particles with zero spin—as yet entirely hypothetical, since no such spinless particles were known—would necessarily have antiparticle partners. Their conclusion, published in 1934, followed from the mathematical structure of quantized fields, and put Dirac’s conjectures about antiparticles on a more solid physical foundation.

In 1936 Weisskopf completed another major article on QED. He returned to the behavior of an electron’s self-field. As many physicists knew by that time, the self-field was complicated because of Heisenberg’s uncertainty principle and the presence of “virtual” particles. In 1927, capping off years of work on quantum mechanics, Heisenberg had deduced that certain pairs of quantities, such as a particle’s position and its simultaneous momentum, could no longer be specified with unlimited precision in the quantum realm. The same held for the energy involved in a physical process, $E$, and the time
over which the process unfolded, $t$: residual uncertainties, $\Delta E$ and $\Delta t$, would remain, subject to $\Delta E \Delta t \sim h$, where $h$ was Planck’s constant. In the context of QED, Heisenberg and others realized, the uncertainty relation meant that even empty space would not be truly empty. Particles could “borrow” energy all the time, popping into existence, as long as they paid that energy back sufficiently quickly. Physicists dubbed these strange, ghost-like particles “virtual particles.”

Quantum-mechanically, the electron’s self-field thus could be pictured as a cloud of virtual pairs of electrons and positrons. Because opposite charges attract while like charges repel, Weisskopf realized that these virtual particles would arrange themselves like the petals of a daisy around the original electron (Figure 3).

The effect would be to polarize the vacuum—that is, even “empty” space would have a definite electrical directionality or orientation. Moreover, the virtual pairs would screen the original electron’s charge, so that an observer would only measure the combined charge of the original electron plus the cloud. Because the virtual particles could borrow any amount of energy whatsoever—even infinite energy—so long as they paid it back quickly enough, the quantum-mechanical contribution to the electron’s charge would be infinitely large. It appeared as if one more infinity had marred QED.

Weisskopf turned this particular infinity into a triumph. He reminded his colleagues that there was no way to turn off the uncertainty principle; virtual particles would always be popping into and out of existence. Thus physicists could never measure the “bare” charge of an electron apart from this virtual cloud. Since the observed charge of an electron was small, it must be that the “bare” charge—never measurable even in principle—was offset by the (infinite) contribution from the virtual particles. The virtual cloud “renormalized” the electron’s charge, leaving a finite overall charge.

Weisskopf completed this last work in Copenhagen rather than Zurich. Although Viki and his wife Ellen had enjoyed their time in Zurich, dangerous reminders about the changing state of Europe intruded. The city’s rich cultural life had been infused by a steady flow of German refugees fleeing Hitler, including many avant-garde artists and actors. Weisskopf himself was hauled before the Swiss Fremdenpolizei (special police force in charge of foreigners) in 1935 and told he would have to leave Switzerland, never to return, as soon as his fellowship with Pauli was over. As far as the authorities were concerned, Weisskopf had too many acquaintances who were Communists or otherwise suspicious. When his appointment ended, he and Ellen returned to Niels Bohr’s institute in Copenhagen. (Twenty-five years later, Weisskopf moved back to Switzerland as a leading scientific statesman; by that time, the earlier, frightening run-in with the authorities could be laughed off.)
War Work
Weisskopf had difficulty finding work in the 1930s because of the worldwide economic depression; his Jewish background only made things harder once the Nazis assumed power. He visited the Soviet Union late in 1936 and considered job offers in both Kiev and Moscow, but decided against moving there: the purge trials that would unleash Stalin’s great terror had already begun. The possibility of a position in the United States seemed much more enticing. Knowing of the budding interest in nuclear physics that many American physics departments harbored—galvanized by Ernest Lawrence’s famous work with cyclotrons at Berkeley—Weisskopf began shifting his research focus while in Copenhagen. He turned his attention to nuclear physics and began publishing for the first time in English, in the American journal, the Physical Review. This strategy, combined with Bohr’s active lobbying on his behalf, led to an offer of a low-level instructorship at the University of Rochester in upstate New York. Weisskopf accepted the job and moved there in 1937.

While at Rochester, Weisskopf continued to pursue his interest in QED while also spending more and more time on nuclear theory. By the time World War II broke out, he was already recognized as one of the most accomplished theorists working in the United States. Not surprisingly, Oppenheimer tapped him to join the budding laboratory at Los Alamos, New Mexico, part of the fast-growing Manhattan Project to design and build nuclear weapons. Weisskopf was among the first to arrive at the laboratory in the spring of 1943; he became second-in-command of the theoretical physics division, serving as deputy division leader under Hans Bethe.

Part of Weisskopf’s task was trying to understand the basic physics of nuclear fission, the process by which certain large nuclei break apart into smaller pieces, releasing energy. Weisskopf focused on how neutrons—tiny nuclear particles that carry no electric charge but interact strongly with other nuclear matter—would behave in and around fissionable material. He developed a keen intuitive sense for these interactions. At one point early in the project, he guessed that the fission cross section (that is, the probability that a neutron would cause a large nucleus to split in two) would rise sharply for neutrons in a particular energy range, even though data for a nearby energy range seemed to indicate otherwise. When newer experimental data vindicated Weisskopf’s hunch, his office was nicknamed the seat of “the oracle”; others teased that it was the “cave of hot air.”

His other main tasks were decidedly more of an applied nature. He aimed to calculate the effects of a nuclear bomb’s detonation: the explosive yield (that is, the force of the bomb’s blast as compared to so many tons of conventional explosives), the shape and force of the shock wave, the extent of radioactivity, and so on. Like his work on fission cross sections, Weisskopf’s approach belied a characteristic trait: he aimed for qualitative description rather than formal
mathematical derivation. Meanwhile, he served for several terms on the Los Alamos town council, including one term as chair or “mayor.” Even in the midst of the world’s largest military-technical project, Weisskopf remained true to his roots. Just as in his “Red Vienna” days, he championed the cause of the low-paid workers and technicians at the laboratory, negotiating on their behalf with the military authorities to improve housing and other features of daily life.

Because of his work on blast effects, Weisskopf was one of the first scientists to relocate late in the war from Los Alamos to the Trinity test site at Alamagordo, New Mexico, two hundred miles south of Los Alamos. (Oppenheimer had dubbed the first test of a nuclear bomb the “Trinity” test, taking the name from a John Donne poem.) For weeks in advance of the July 16, 1945, test, Weisskopf helped set up measuring devices and diagnostic tools at various check-points. He was among the handful of theoretical physicists who witnessed the explosion, seeing the characteristic mushroom cloud rise above the desert.

Weisskopf and some colleagues had calculated that thirty-six hours after the detonation, residual levels of radioactivity at “ground zero” should fall low enough to allow brief inspections. And so Hans Bethe, Enrico Fermi, and he strapped on radiation-measuring tags and drove a Jeep down to the blast site a day and a half after the test. What they saw amazed them. Not only had the scaffolding and other equipment in the immediate vicinity of the bomb been vaporized, but the force and heat of the blast had even fused the desert’s sand into glass (later dubbed “trinitite”). This physical transformation gave Weisskopf a visceral sense of the bomb’s power. To his chagrin, the presence of trinitite seemed to hold little special meaning for the military officials, including General Leslie Groves, overseer of the entire Manhattan Project.

Postwar Research
Immediately after the war, Jerrold Zacharias recruited Weisskopf to move to the Massachusetts Institute of Technology. By 1946, Weisskopf had joined MIT’s physics department.

Soon he was back into the thickets of QED. He began working with MIT graduate student Bruce French to calculate the energy levels within hydrogen, taking into account effects from virtual particles. They received extra impetus to plow through their laborious calculation in 1947, when Columbia University’s Willis Lamb announced that he had measured a miniscule—but
non-zero—energy difference between two particular states of hydrogen, even though quantum mechanics predicted they should have precisely the same energy. Weisskopf compared his calculated value for the “Lamb shift” with both Richard Feynman and Julian Schwinger—two young guns of theoretical physics who had separately worked out new ways to calculate the effects of virtual particles in QED. To Weisskopf’s disappointment, Feynman’s and Schwinger’s calculations matched each other but differed from that of Weisskopf and French. Congenitally unsure of himself, Weisskopf held his paper back until he and French could find their error. In the meantime, Lamb himself published a theoretical study of the energy-level shift, along with his graduate student Norman Kroll. Lamb and Kroll had arrived (independently) at the same result as Weisskopf and French. Six months later, Feynman sheepishly called Weisskopf to apologize: he and Schwinger had been the ones in error, and Weisskopf and French had been correct all along!

The mix-up marked one of Weisskopf’s last active encounters with QED. Beyond this tragi-comic snafu, however, several of Weisskopf’s earlier insights finally bore fruit. Building on Weisskopf’s work on self-energy, vacuum polarization, and charge renormalization, Schwinger, Feynman, Sin-itiro Tomonaga, and Freeman Dyson pieced together a successful renormalization program between 1947 and 1949. At long last, the infinities that had long plagued QED had been banished, leaving behind finite numbers that stood in remarkably good agreement with the latest experimental results.

By this time, Weisskopf’s own interests had turned squarely to nuclear theory. Working closely with fellow MIT theorist Herman Feshbach, as well as several graduate students (especially David Peaslee and Charles Porter), Weisskopf developed a string of successful models of nuclear behavior. Like the best of his wartime work, these models featured intuitive approaches and clever rules-of-thumb rather than mathematical rigor. Weisskopf’s particular brand of nuclear theory also infused his major textbook, written with MIT postdoctoral fellow John Blatt, *Theoretical Nuclear Physics* (1952). Quickly considered the “bible” for the subject, this influential textbook had the distinction for several years of being the most frequently stolen book from the MIT libraries!

During this period, Weisskopf trained twenty-one MIT Ph.D. students, including such accomplished theorists as J. David Jackson, Kurt Gottfried,
Kerson Huang, J. Dirk Walecka, and Nobel laureate Murray Gell-Mann. He also stepped up his activities beyond the classroom. He was among the original eight members of the “Emergency Committee of Atomic Scientists,” founded in 1946. The brainchild of Leo Szilard and chaired by Albert Einstein, the Emergency Committee sought to educate the public and politicians about the dangers of a run-away nuclear arms race. At the same time, Weisskopf also helped to found the Federation of Atomic Scientists (FAS, later changed to Federation of American Scientists), which likewise lobbied for civilian rather than military control of atomic energy. Soon the FAS’s mandate widened to combat the excesses of McCarthyism. Weisskopf served for many years on the FAS executive council, and also chaired its committee on visas. During the late 1940s and early 1950s, the U. S. State Department frequently denied visas to foreign scientists deemed to be politically suspect; Weisskopf testified before the U. S. Congress in 1952 to argue for a reform of the system. A few years later, he joined the budding Pugwash movement (founded in 1957), devoted to halting the nuclear arms race.

**Leading CERN**

Fifteen years after moving to MIT, Weisskopf took an extended leave of absence. He had been invited to serve as director general for CERN (the European Organization for Nuclear Research), a new multinational laboratory for high-energy physics in Geneva, Switzerland. First proposed in 1950, the laboratory was operating by 1954. It achieved its first beam of accelerated protons in 1959; Weisskopf became director general in 1961.

Part of the attraction for Weisskopf was the opportunity to learn more about particle physics, which by this time had separated into a distinct specialty from nuclear physics. In addition to immersing himself in the day-to-day activities at the laboratory—he took inspiration from Oppenheimer’s leadership style at wartime Los Alamos—he also began to deliver popular lectures on the state of the field for students and new arrivals at the laboratory. The lectures became a long-running tradition, featuring Weisskopf’s famously conceptual, intuitive approach. He later wrote up the lectures with his former graduate student, Kurt Gottfried, as the two-volume textbook, *Concepts of Particle Physics* (1984, 1986).

Weisskopf served as director general for nearly four and a half years (August 1961—December 1965), and left two principal legacies. First was his strong backing of the controversial decision that the next major accelerator at the laboratory should be a colliding beam machine rather than a fixed-target accelerator. Until that time, particle accelerators worked by speeding up a beam of particles and smashing them into a stationary target, so that physicists could study the debris that came out. Weisskopf insisted instead on forging ahead with an “intersecting storage ring” (ISR) design, in which two beams
of protons were separately accelerated and then made to collide head-on. Although more difficult to build, the interaction energies achieved by such a machine promised to rise much higher than conventional accelerators had achieved; and in high-energy physics, higher energies was the name of the game. (The interaction energy in a colliding beam machine scaled roughly as the square of the energy of an ordinary fixed-target device.) Plans took shape during Weisskopf’s tenure, and the ISR came on-line in 1971.

Second, Weisskopf concluded negotiations with the French government to expand the laboratory beyond Swiss soil. The new real estate proved crucial to the ISR and to later developments at the laboratory. Thanks to Weisskopf’s diplomacy, protons now cross the Swiss-French border billions of times each second as they get whipped around to higher and higher energies. Weisskopf thus planted the seeds for the Large Hadron Collider (LHC), which should achieve the highest interaction energies of any accelerator on earth.

Later Work
Weisskopf returned to MIT early in 1966. He continued to work with younger theorists on nuclear and particle theory. His role increasingly became that of a wise sounding board, offering counsel to graduate students, postdocs, and young faculty alike. He excelled in this role, as in the mid-1970s, when he and several younger colleagues developed a new model for the structure of nuclear particles. Dubbed the “MIT Bag model,” their work built upon the latest discoveries in particle theory. The paper appeared in 1974.

Just a few months earlier, theorists at Harvard (H. David Politzer) and at Princeton (David Gross and Frank Wilczek) separately found that the strength of the strong nuclear force becomes weaker the closer one approaches the sub-nuclear particles, or “quarks,” within protons and neutrons. Conversely, the strong force becomes stronger with increasing distance. This is exactly the opposite of how more familiar forces behave, such as electromagnetism, which led to the self-energy divergences that Weisskopf first tackled in the 1930s.

Until the mid-1970s, no one had made much progress in trying to calculate the effects of the strong nuclear force from first principles, precisely because its strength ruled out perturbative approaches. (The same stumbling block had led Weisskopf, Feshbach, and their students to try phenomenological approaches, such as the “clouded crystal ball” model, twenty years earlier.) Armed with the news that the strong force actually became weak at short distances, several young MIT theorists—Alan Chodos, Robert Jaffe, Kenneth Johnson, and Charles Thorn—together with Weisskopf, introduced a new way to study the behavior of neutrons and protons. In a typical Weisskopfian move, they simplified the problem, honing in on the essentials without getting bogged down in mathematical details.
They pictured protons, neutrons, and similar nuclear particles as “bags” filled with quarks. Because the strong force grew in strength with increasing distance, they simply hypothesized that the quarks remain rigidly contained within some volume (the “bag”); but at shorter distances (within the bag), the force between quarks fell rapidly, and so it could essentially be ignored altogether. Treating protons and neutrons as bags filled with free (that is, noninteracting) quarks sidestepped most of the horrendously complicated dynamics, allowing the theorists to make rapid progress in estimating how real nuclear particles behave. Although Weisskopf often joked that all he had contributed to the study was the “don’t-know-how,” his younger colleagues insisted that his name appear with theirs as an author. In fact, explained Jaffe, Weisskopf had supplied some of the crucial statistical arguments that the group employed, hearkening back to some of Weisskopf’s own work from the 1930s and 1940s.

Weisskopf reached the mandatory retirement age in 1974, after which he spent even more time in leadership roles around the world. He continued his decades-long work on nuclear policy, encouraging Pope John Paul II to speak out against the horrors of nuclear war and the importance of arms control, a topic the pope championed during the early 1980s. Weisskopf also built upon his earlier success as a popular-science author, publishing The Privilege of Being a Physicist (1989) and his scientific autobiography, The Joy of Insight (1991), to complement his acclaimed Knowledge and Wonder (1962) and Physics in the Twentieth Century (1972).

Weisskopf died in 2002 at the age of 93. During his long career, he published nearly four hundred scientific articles, technical reports, textbooks, and popular books about science. He often remarked that he had “lived a happy life in a dreadful century.” He was survived by his second wife, Duscha Scott, his two children, Thomas and Karen, and several grandchildren.

To learn more about Victor Weisskopf

English translations of Weisskopf’s most important articles on quantum electrodynamics are available in Early Quantum Electrodynamics: A Source Book, edited by Arthur I. Miller (New York: Cambridge University Press, 1994). His textbooks, popular writings, and autobiography all make excellent reading as well:


Works about Weisskopf include:


David Kaiser is an Associate Professor of the History of Science in the MIT Program in Science, Technology & Society, and a Lecturer in the Department of Physics. He received his Ph.D. in Physics and History of Science from Harvard University in 2000, and an A.B. in Physics with Highest Honors from Dartmouth College in 1993. Kaiser’s many awards and honors include MIT’s 2006 Harold E. Edgerton Faculty Achievement Award and the 2001 Levan Prize in the Humanities, as well as the 1993 Apker Prize from the American Physical Society. He has published several books and edited volumes, of which his first book, Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics (University of Chicago Press, 2005), received critical praise for being ‘the definitive study of one of the great ubiquitous tools of modern quantum field theory.’ Kaiser’s upcoming book, American Physics and the Cold War Bubble, will be published by the University of Chicago Press.
Wayne Hazen (SB. Thesis advisor: Wayne Nottingham.) attended an MIT Town Meeting this winter of physicists who were concerned with the impeding demise of Institute shop facilities. Otherwise, his “professional activity” consists of a weekly brown bag lunch with several retired physicists at the University of Michigan, with whom he also travels a bit, e.g., to NYC for ballet, opera, etc.

Frank Jamerson (SB. Thesis advisor: David Frisch.) published the 2007 edition of Electric Bikes Worldwide Reports (ebwr.com). Twenty million Light Electric Vehicles were sold world-wide this year. Booming sales in China and India, in addition to growth in Europe and the U.S., suggests 50-100 million LEV units a year will be sold by 2017. Electric transportation is here!

Arthur Winston (PhD. Thesis advisor: Louis Osborne.) was the co-recipient this year of the National Academy of Engineering’s Bernard M. Gordon Prize for Innovation in Engineering and Technology Education. He is a former President and appointed Life Fellow of the IEEE, and remains active in pre-college issues for the organization.

Bjarne E. Ursin (SB) is spending a lot of time studying and working with super string, QED, and quantum gravity theories. The balance of his time is devoted to chairing legislative activity and education for safe boating in the U.S.; hobbies at home; and visiting children and grandchildren.

Jason Taylor (SB. Thesis advisor: Louis Osborne.) In the ‘90s, Jason taught math and physics at Bentley College as physics department head. He was also an adjunct instructor in MIT’s Writing and Humanistic Studies program, until his car was stolen in front of Walker. This year, Jason wrote and illustrated a children’s book for pre-readers through third grade, EduFables, published in May 2007.

James Schecher (SB. Thesis advisor: Sandborn Brown.) retired from PRC, where he had been a computer programmer.

Walter Helly (PhD. Thesis advisor: Philip Morse.) Aside from advisor Philip Morse, others who helped Walter along included Herman Feshbach and Bob Herman (then of General Motors). Today, Walter polishes antique cameras and takes cruises.

Burnell G. West (SB. Thesis advisor: David Luckey. PhD ’65, Colorado University.) was elected a Life Fellow of the IEEE in December 2005, which will come as quite a surprise to those of his friends in the MIT physics class of 1960, who may still recall how he was all thumbs in electronics lab. This event was followed by another career highlight: retiring in August of 2006.


Bruce Tarter (SB. PhD ’67, Cornell University.) retired from the Lawrence Livermore National Laboratory in 2004, after 37 years of employment, where he served as Director from 1994–2002. He continues to work part-time at the Lab (mostly on its history), while serving on the Board of Directors of Draper Laboratory.

Last year, Bruce chaired a national security panel of the American Association for the Advancement of Science, which released the report, “The United States Nuclear Weapons Program: the Role of the Reliable Replacement Warhead.” He found it a fascinating technical and political project, but was reminded of how much more work is involved in chairing a group, rather than in simply being a participant.


Gary J. Linford (SB. Thesis advisor: Charles Townes. PhD ’71, University of Utah.) has been supporting the development of Prometheus inertial confinement fusion power plants. He considers the technology involved to be the solution to eliminating greenhouse gases and politically-motivated oil cartels.

Walter A. Simmons (SB. PhD ’69, Purdue University.) and his colleague S. Pakvasa posted a research paper on April 7, 2007, on quantum geometric phase.

Neal Carron (SB) recently published the physics textbook, useful in radiation studies, An Introduction to the Passage of Energetic Particles Through Matter. It’s available on-line, and its author welcomes feedback from fellow alums: ncarron@alum.mit.edu.

Gene Sprouse (SB. PhD ’68, Stanford University.) was appointed Editor-in-Chief of the American Physical Society (APS) in March 2007. As one of three co-equal operating officers of the APS, his
primary responsibility is the Physical Review series of physics journals. Sprouse is on leave from his professorship at Stony Brook University.

'65 Andy Tanenbaum (SB. Thesis advisor: Minoru Oda.) is still a Professor of Computer Science at the Vrije Universiteit in Amsterdam. Last year, he managed to publish over a dozen papers, of which two won “Best Paper” awards. His MINIX 3 system (minix3.org) is starting to take off; it was downloaded almost 200,000 times in the past year. All in all, it is full steam ahead for Andy.

J. Craig Wheeler (SB. Thesis advisor: Charles Townes.) is currently President of the American Astronomical Society, where he’s leading efforts to grow its publications, The Astrophysical Journal and The Astronomical Journal, as well as expanding communication amongst the Society’s membership. Craig’s own research involves the astrophysics of exploding stars, with implications ranging from astrobiology to the “dark energy” driving the mysterious acceleration of the Universe. The second edition of his popular-level book, Cosmic Catastrophes: Exploding Stars, Black Holes, and Mapping the Universe, was recently released by Cambridge University Press. The film of his novel, The Krone Experiment, is available on DVD at thekroneexperiment.com.

’70 David Cannell (PhD ’70, SB ’65. Thesis advisor: George Benedek.) is a Professor of Physics at the University of California, Santa Barbara, where he’s now responsible for half of a flight experiment to test fundamental fluid properties, i.e., fluctuations in a fluid driven out of equilibrium by a heat flux. The experiment—named Gradflex (GRAdient Driven FLuctuations Experiment)—is a collaboration with Marzio Giglio of the University of Milan, whom David first met while a student in George Benedek’s group in the late ’60s. Gradflex is scheduled to be flown in a satellite for 12 days, beginning September 14, 2007. It’s part of the European Space Agency’s Foton M-3 mission.

’71 James M. Turner (PhD. Thesis advisor: Joseph Binsack.) was selected as Deputy Director of the U. S. Department of Commerce’s National Institute of Standards and Technology (NIST), where he’ll manage NIST’s daily operations and assist in setting strategic directions. Prior to joining NIST, James served as Assistant Deputy Administrator for Nuclear Risk Reduction in the U. S. Department of Energy’s National Nuclear Security Administration.

’72 James N. Hallock (PhD ’72, SB ’63. Thesis advisor: Harald Enge.) After more than 20 years as Manager of the Aviation Safety Division at the Department of Transportation’s Volpe Center, James was promoted to Senior Technical Expert for Air and Space Transportation Safety. The “space” part of the new title derives from his participation as a member of the space shuttle Columbia Accident Investigation Board in 2003. Now Jim can spend all his time on technical problems.

’73 Steve Berger (PhD ’73, SB ’67. Thesis advisors: Bernard Feld, Lee Grodzins.) continues to teach and mentor in the New York City public school system in Queens. He’s tutoring students in the general areas of physics, math, and physical chemistry. In 2006, Steve received a “Master Instructor” award for superior teaching. Viola Szasz Ruck (SB. Thesis advisor: Sergio Fubini.) was promoted to Professor of Physics at North Lake College, Irving, TX. As a President’s Scholar, she delivered the school’s commencement speech this spring.

’75 Francine Wright Bellson (SM. Thesis advisor: Daniel Kleppner.) designed, produced, and released her husband’s latest CD, The Sacred Music of Louie Bellson, available through cdbaby.com/louie-bellson or (800) 645-6673.

’77 David Batchelor (SB. Thesis advisor: Stanislaw Ulbert. PhD, University of North Carolina, Chapel Hill.) is a radiation physicist at NASA’s Goddard Space Flight Center, where he first arrived in 1980 to study radiation from solar flares as a graduate student. His current research is on performing forecasts of radiation doses that must be tolerated by proposed spacecraft. He considers it an opportunity to ensure the safety and success of the future moon missions in the Constellation program, and it’s his first involvement with the human spaceflight projects.

’79 James F. DeBroux (SM. Thesis advisor: Margaret MacVicar.) In mid-2006, Jim moved from his position as Group Director for Business Operations in the Advanced Concepts business unit of L-3 Communications-SYColeman to become the Vice President of Washington Operations for Digital Fusion, Inc., a small Huntsville-based company that specializes in research and engineering, IT, and acquisition and business support services. Digital Fusion works
primarily in the Federal sector and focuses on supporting space, missile, and aviation functions at Redstone Arsenal, AL.

‘82

Jose Antonio Garcia-Barreto (PhD. Thesis advisor: Bernard Burke.) is an Associate Professor at the Institute of Astronomy at the National Autonomous University of Mexico. In October 2006, he published a new book, co-authored with Julio Martínez, *Solutions to Problems in Electromagnetic Theory*, a reference textbook for physics or mathematics graduate students.

‘84

Cyrus Taylor (PhD ’84, SB ’80. Thesis advisors: Ken Johnson, Philip Morrison.) was named interim Dean of the College of Arts and Sciences at Case Western Reserve University in July 2006 and permanent Dean in January 2007.

‘85

Nuri Dagdeviren (PhD. Thesis advisor: Arthur Kerman.) After spending two years in Seoul, Korea, managing Agere Systems’ mobile phone business with Samsung, Nuri is now the President of PINC Solutions in Berkeley, CA.

Megan Donahue (SB. Thesis advisor: Claude Canizares.) is a Professor of Astronomy and Physics at Michigan State University, where she studies clusters of galaxies using the three operational NASA Great Observatories: Chandra, Hubble, and Spitzer. In 2006, she was elected to a three-year term as councilor of the American Astronomical Society. Megan is also the co-author, with Jeffrey Bennett, Nicholas Schneider, and Mark Voit, of two popular introductory astronomy textbooks, *The Cosmic Perspective* and *The Essential Cosmic Perspective*, now in their fourth editions.

‘86

Stephen Y. Chou (PhD. Thesis advisors: Henry I. Smith, Marc Kastner, Dimitri Antoniadis.) was elected a member of the National Academy of Engineering this year “for contributions to nanoscale patterning and to the scaling of electronic, photonic, magnetic and biological devices.” Steve is the Joseph C. Elgin Professor in the Department of Electrical Engineering at Princeton University.

‘88

Ofelia C. de Hodgins (SM. Thesis advisors: Keith Johnson, Donald Uhlman.) is a Six Sigma Black and Lean Enterprise Master, as well as the author of over thirty-two articles in scientific and technical journals, and more than 25 years in process engineering and excellence.

Joseph Harrington (SB. Thesis advisor: James Elliot. PhD ’95, *Earth, Atmospheric & Planetary Sciences*) moved this year from a research position at Cornell University to a faculty position at the University of Central Florida. His research group recently made the first detection of thermal variations on an extrasolar planet, which was also the first direct detection of a non-transiting planet (published in *Science*). A subsequent *Nature* paper presented the first exoplanetary emission spectrum, with more announcements yet to come.

Ernest N. Prabhakar (SB) After three years spent in Sacramento while his wife pursued a residency in family medicine, Ernie moved back to the San Francisco Bay area. He’s still the Open Source Product Manager at Apple, as well as a Board Advisor to the Open Source Initiative, and regularly runs into many MIT alumni.

‘90

Marian (Shih) Kinnicutt (SB. Thesis advisor, Donald Heimann. PhD ’95, *University of Michigan*) was recently promoted to full Professor of Physics at Saginaw Valley State University, Michigan, where she continues to serve as Chairperson of the Physics Department. Marian remembers with fondness her undergraduate thesis advisor, Don Heimann, and how he taught by example the importance of dealing fairly with all scientists when doing research. She also enjoys reminiscing about the other physics faculty whose classes she took, and tries to emulate them when teaching her own courses. She and her husband delight in watching their three-year-old daughter Emily growing up.

‘91

John T. Chen (SB. Thesis advisor: Stephen Meyert.) After spending several years working in both industry and start-ups, John joined Silicon Valley venture capital firm Battery Ventures, Inc., two years ago, and has enjoyed every minute of it. He spearheads the firm’s investments in advanced materials, nanotechnology, and clean technology companies, and has, in addition, completed the second year of his Kauffman Fellowship with Battery Ventures. John’s always on the lookout for promising technology companies that leverage materials science, and welcomes the chance to discuss opportunities with any MIT alumni (jchen@battery.com).

Michael Lercel (SB. Thesis advisor: Marc Kastner. PhD ’96, *Cornell University*) was appointed Director of Lithography at SEMATECH in 2006, after serving as Associate Director. Along with the dynamics of the semiconductor lithography roadmap, Michael finds that balancing the research efforts in extending optical lithography and emerging litho technologies is a challenge.
Matt McCluskey (SB. Thesis advisor: Jonathan Wurtele.) was Acting Chair of the Department of Physics and Astronomy at Washington State University this past year. He recently received a Department of Energy grant to study the optical and magnetic properties of zinc oxide nanoparticles doped with transition metals.

Edward A. Ajhar (PhD ’92, SB ’86.) currently serves as Chair of the Department of Natural Sciences, Mathematics, and Computer Sciences at St. Thomas University, Miami Gardens, FL. He was recently named Interim Dean of the newly formed School of Science, Technology, and Engineering Management.

Scott Seo (SB. Thesis advisor: Walter Lewin.) After receiving an M.S. in Physics from the University of Wisconsin in 1994, Scott completed an M.D./Ph.D. at Baylor College of Medicine in 2003. He just completed his fourth and final year of residency training in Ophthalmology at Johns Hopkins, and joined a private practice in Connecticut.

Denise Ciotti Labieniec (SB.) still chairs the science department at The Winsor School for Girls in Boston, while teaching several levels of physics. Her big news is that she and husband Michael have welcomed a new son, Nicolo, into the world. Denise can’t believe she used to think that the all-nighters she pulled for quantum problem sets as an undergrad were bad...it’s nothing compared to feeding a newborn!

Ted Sung (PhD. Thesis advisor: Stephen Steadman.) has been keeping busy, particularly with his kids. He has a teenager, Jonathan, who just turned 13, as well as two girls: Leilani (9) and Michelle (6). For several years now, Ted has been coaching Jonathan and Michelle’s soccer teams, which has helped him to appreciate all the coaches he himself had in his time. He still plays soccer himself, as well as a lot of ice hockey in the winter. Since graduating from MIT, Ted has worked as a software developer at Intex Solutions, which specializes in structure finance.

Kevin Borland (SB. Thesis advisor: Earl Lomon.) was licensed and admitted to practice law in Virginia in March 2007. In his spare time, Kevin has begun preparing a database for comparing syntactical and lexical features of the Germanic languages and has done work in reconstructing proto-languages in the family, with emphasis on conversational usage. He has also done some independent research on the geographical features of the Pacific Rim mountain ranges this year, and took a road trip with his wife and son, encompassing nearly the entire length of the American Rockies.

Karen Thibault Bodnar (SB) recently earned an M.D. from the University of Florida, and will remain in Gainesville to complete a pediatric residency. She’s also happy to announce the birth of a daughter, Amelia Mae, in January 2007.

Edward Daw (PhD. Thesis advisor: Leslie Rosenberg.) is a lecturer in Physics and Astronomy at the University of Sheffield, U. K. His research involves experiments searching for weakly interacting dark matter, as well as experimental searches for gravitational waves. He is married to Anne Daw (MIT, M.Arch, 1998), with whom he has two children, Georgia (3) and Eli (1).

Andrew Howard (SB. Thesis advisor: Thomas Greytak.) was awarded the Ph.D. in Physics from Harvard University in June 2006 for work with Paul Horowitz on optical SETI (the Search for Extraterrestrial Intelligence). Last year was also notable for his personal life, as he married Sarah Muirhead in Olympic National Park. What a year! In the summer of 2007, he began a Charles Townes Postdoctoral Fellowship, working with Geoff Marcy on searches for extrasolar planets.

Eric B. Ford (SB. Thesis advisor: Frederic Rasio.) This summer, Eric moved from the Harvard-Smithsonian Center for Astrophysics to the University of Florida, where he has accepted a position as an Assistant Professor in the Astronomy Department.

Noah Bray-Ali (SB. Thesis advisor: Uwe-Jens Wiese.) After nine long years, Noah has made it back to his native Los Angeles. His current postdoc at the University of Southern California in the physics and astronomy department allows him to continue developing interests in condensed matter physics, first kindled at MIT by courses with Tom Greytak and Kerson Huang. After MIT, Noah spent a summer at the University of Tokyo as a participant in the MIT-Japan program, followed by UC-Berkeley’s Ph.D. program in physics.

Baruch Feldman (SB. Thesis advisor: Uwe-Jens Wiese.) is working on his Ph.D. in applied condensed matter theory with Prof. Scott Dunham at the University of Washington. He hopes to have his second publication and take the general exams this quarter.
Joshua Weitz (PhD. Thesis advisor: Daniel Rothman.) This January, Joshua began a position as an Assistant Professor in the School of Biology at Georgia Tech. He received a Career Award at the Scientific Interface from the Burroughs Wellcome Fund, in support of his interdisciplinary research on the evolutionary ecology of bacterial viruses.

Alex Wissner-Gross (SB, Physics/Electrical Engineering/ Mathematics. Thesis advisor: Bolek Wyslouch.) is completing his Ph.D. in Physics as a Hertz Fellow at Harvard University. He was recently awarded the 2007 Dan David Prize Scholarship for Future Energy applications; the 2007 Graduate Student Silver Award from the Materials Research Society; and named one of the top six scientific film directors in the 2006 Materials Research Film Festival. Alex was also featured in New Scientist, and is the recipient of numerous physics teaching awards for his Wikipedia-based reading list generation software. More information is available at alexwg.org.

Xiaochao Zheng (PhD. Thesis advisor: William Bertozzi) In August 2006, Xiaochao accepted a position as an Assistant Professor of Physics at the University of Virginia, Charlottesville. Her area of research is experimental medium energy physics. Although she had never taught before joining UVA, at the completion of her first year she was awarded a University Teaching Fellowship.

Annemarie Grandke (SB. Thesis advisor: Thomas Greytak.) After receiving her M.Phil. in Politics from Oxford University in June 2006, Annemarie joined the Munich office of The Boston Consulting Group, where she focuses primarily on the consumer goods industry. The closest she has come thus far to doing any physics was when examining the physical implications of high pressure pasteurizing hazelnuts.

Michelle L. Povinelli (PhD. Thesis advisor: John Joannopoulos.) This June, Michelle was awarded a Fellowship for Women in Science, sponsored by L’Oreal-USA. The prize provides $20,000 of research funding to each of its five recipients, selected from a national applicant pool across all scientific disciplines.

Julia Steinberger (PhD. Thesis advisors: Thomas Greytak, Daniel Kleppner.) After a few career detours, including a stint as a radio news reporter in Geneva and participating in the 2005 United Nations World Summit for the Information Society, Julia found a new home in academia in the field of industrial ecology. Since May 2006, she has been a postdoc at the Universities of Lausanne and Zurich, and has accepted a position as a senior researcher at the Institute for Social Ecology of the University of Klagenfurt in Vienna.

Nasruddin Nazerali (SB) is glad to be back at MIT after one year of teaching high school mathematics, and hopes to complete his M.Eng. in Environmental Engineering this year. He’ll join the MIT Earth, Atmospheric and Planetary Sciences department’s Geophysics Ph.D. program this fall.

Sean P. Robinson (PhD ’05, SB ’99. Thesis advisors: Frank Wilczek, Edward Farhi.) Since June 2005, Sean has been the MIT Physics Department’s primary coordinator for construction of the new Green Center for Physics. With that now ending, he moves to the position of Technical Instructor, also in the MIT Physics Department, and will be involved in both 8.01 TEAL and 8.13 Junior Lab this fall. Sean continues theoretical research in general relativity and quantum field theory. He lives in Marshfield, MA, with his wife and two children.

David Chan (PhD. Thesis advisor: John Joannopoulos.) After finishing his Ph.D., David moved to New York and joined Goldman, Sachs & Co., as a strategist working in the equities division. In his spare time, when not performing FDTD simulations on stock indices and looking for exponentially divergent components, David can often be found running along the East River, schmoozing at cocktail parties, and enjoying the many cultural events that Manhattan has to offer.

Amanda Frye (SB) Since July of 2006, Amanda has been teaching physical science and physics to high school students in the Philadelphia public schools through Teach for America. She finds her students to be some of the brightest, most imaginative and amazing students she has ever met. Most of her students are lacking skills in math, so Amanda does a lot of conceptual and hands-on physics with them. Her MIT training has served her well in making amazing demonstrations possible on a shoe-string budget.
Neil Pappalardo in conversation with Associate Professor Erik Katsavounidis.

A. Neil (SB EE ’64) & Jane Pappalardo

Watch Neil Pappalardo as he questions junior faculty on the exact number of exoplanets, or how specifically gravitational waves can be measured, and you’ll see the passion and persistence behind the MEDITECH founder and father of four. A child of Sicilian immigrants from a small village outside of Rochester, New York, Neil came to MIT, studied physics, and went on to found one of the largest privately-held software companies in the world.

When he was in the 8th grade, Neil Pappalardo announced to his parents he would attend MIT. He knew it was a prestigious institution that smart people attended but not much more. His parents enrolled him at a Jesuit high school where he was encouraged to study the classics rather than focusing on the math and science skills that he would later learn at MIT. Neil followed this advice and took four years of Greek and Latin. He graduated from the high school without a single science class and a mere two years of math. During his junior year he visited MIT and was surprised to find that the Institute had course requirements for admission and that science and math were high on the list. Undaunted, as math had always come easily, Neil scored well on his SATs, and applied to the one school his heart was set on. He was the first from his high school to attend MIT.

Neil has always loved physics, particularly astrophysics and cosmology, and for three and half years he was a course 8 major with every intention of graduating with a physics degree. But then something happened. He learned he had to write a thesis in order to graduate and it had to be something original and creative. A professor in the electrical engineering department suggested Neil talk to some cardiologists who had a problem and needed help. Neil agreed to help the physicians by developing a medical device that would electronically examine the electrical signal from a patient’s heart.

“Throughout our entire marriage, there has been a stack of physics and cosmology books piled next to Neil’s side of the bed.”

—Jane Pappalardo
Neil met his future wife, Jane Langevin, in October of his senior year. Jane remembers, “We met at 2:30 in the afternoon at his fraternity. Neil was just getting out of bed. Classes held no interest for him and he would sleep late every day. Soon afterward, they were ‘pinned’ (remember, this was 1963). Neil and Jane were engaged in January 1964 and married that August. After graduation, Neil worked at Mass General Hospital, where he began to write the software that would automate the hospital’s clinical laboratory. “Because I was so totally unaware of the scope of this undertaking, I was undaunted,” he notes. For the next few years, Neil continued to search out other areas within the hospital ripe for automation.

In November 1968, Jane announced she was pregnant with their fourth child. Neil decided the time was right to create his own company to provide the software automation solutions he had developed and market them to other hospitals. He put together a business plan and began knocking on the doors of venture capitalists. There were two problems: he was an inexperienced 26-year-old, and no one knew what software was. Nevertheless, he persevered and eight months later, on August 4, 1969, both Medical Information Technology (MEDITECH) and Missy (the baby) were born.

When Neil met Jane, she was majoring in music with an emphasis in piano. Appropriately, Neil decided he would get Jane a piano for their first wedding anniversary. At the time, he was working at Mass General while taking software classes at MIT, and money was tight. He had been to the Baldwin piano store and made an arrangement to pay them $600 for a brand new piano. To raise the money, Neil sold his blood every month at the hospital. That June, Jane graduated; in July, their first child, Michael, was born; and in August, Neil presented Jane with the piano. Neil is emphatic when he notes that his family is the most important thing in his life, and further, “without Jane, I’d be dead!” Neil and Jane, their four children and 11 grandchildren, make it a priority to spend as much time together as possible.
Today MEDITECH is one of the world’s oldest software companies. Its integrated information system is installed in more than 2,000 hospitals throughout the United States, Canada, and the United Kingdom. Neil mentions that he is very proud of the fact that MEDITECH hires only entry level employees and promotes only from within. The company has five unique locations situated along Route 128 just outside Boston and is currently building a new 130,000-square foot facility on a 17-acre site in Fall River, MA, for customer service and training. “I only buy top quality buildings with unique attributes that can provide an enjoyable work space for our employees.” One facility has a race track, another sits in the middle of a golf course. Each facility comes with elegant employee dining areas, common spaces with abundant natural light, and numerous works of art, many by local artists.

When he’s not at MEDITECH, Neil’s at MIT. He is a life member of the MIT Corporation and serves on the Corporation’s Executive and Auditing Committees, as well as three visiting committees, for Mechanical Engineering, the Libraries and Physics. Jane, who graduated from Boston University with a degree in music, is a member of the MIT Council of the Arts.

Neil’s renewed involvement with the Physics Department began in earnest in 1996. There was some concern that MIT’s astrophysics division might become in danger of losing out to competitive institutions in attracting the younger generation of astrophysicists. The Department needed access to one of the world-class optical telescopes that were then being built. Neil listened when Professors Claude Canizares and Paul Schechter talked about the critical difference this access would make for the Department. It was a very straightforward argument: “With a giant telescope we’d be able to attract brilliant young astronomers and the most promising graduate students.” Supporting the Magellan telescopes project was clear cut. Neil and Jane decided to help fund the construction of the world-class Magellan optical telescope observatory in Chile. “What we set out to accomplish, we accomplished. Today, astrophysics at MIT is second to none.”

“Whenever I make a gift, I make sure that the gift will make the Department even better than it is.”

—Neil Pappalardo
young physicists. Again, convinced it would make the Physics Department even stronger, Neil told Marc and Dean of Science Bob Birgeneau just how it could be done and how it could be financed. Nine years later, the Pappalardo Fellowships in Physics is one of the most prestigious and emulated programs of its kind in the world. Professor Bob Jaffe, former Director of the Center for Theoretical Physics, calls Neil “a visionary supporter of the MIT Physics Department. The Pappalardo Fellowship Program has made the Department the destination for the brightest young physicists.” Current Pappalardo Fellow Henriette Elvang echoes her colleagues when she calls Neil and Jane “amazing.” She explains: “They genuinely care about us and our careers. Their level of personal engagement is just mind-blowing; they come to our presentations [annual Pappalardo Fellowships symposium] and they want to see us do well. We are invited into their home, we know their family and they know ours. It’s a unique situation and we all feel very fortunate.” Three former Fellows thus far have joined the MIT physics faculty, and many others have gone on to tenure track positions at other prestigious institutions.

For 25 years, the Physics Department has dreamed about and worked for a home of its own on campus. In August 2002, an arrangement was reached, at last, to bring most of physics together in Buildings 4, 6, and 8. The Department thought it had the go-ahead but in the final hour, the Institute administration said more money was needed. Despair and discouragement filled the infinite corridor around Building 6 until Neil, once again, came to the rescue. Neil said he and Jane would provide $5 million for the project if the Department could raise an additional $5 million. With this challenge and an influx of optimism, encouragement, and persistence, the Department raised the additional $5 million in less than a year.

The Green Center for Physics will be dedicated on October 5, 2007. The MIT Department of Physics is in the best shape ever, and in large part, we have Neil and Jane to thank for it.

“Neil Pappalardo is the soul of the Physics Department.”
—Frank Wilczek, Herman Feshbach Professor Physics; 2004 Nobel Laureate
Fascinated by astronomy throughout his childhood, Howard spent weekends as a teenager at the American Museum of Natural History Planetarium, where he became President of their Junior Astronomy Club. He had his own 3" refractor and free access to the Rutherford Observatory at Columbia University when he heard that the downtown NYU campus had an underutilized IBM computer and a Director who liked working with high school kids. Howard remembers, “I thought it would be great to use the computer on astronomy projects. Before I knew it, the second great intellectual passion of my life, computer science, was born.”

Howard Messing entered MIT in 1969 at age 16. He wanted to concentrate in both physics and computer science and although he did take the full physics sequence, computer science narrowly edged out physics and he graduated with a degree in Course 6. He then began a Ph.D. program in computer science but ended up back in Boston to get a job and save money before returning to graduate school. Howard went for an interview at a hospital software company called MEDITECH. “Neil Pappalardo, then president, conducted a Socratic-style interview with me, leading me through some basics of programming language theory. I was fascinated, for now I could do what I loved and get paid for it!” Thirty-three years later, Howard is President and Chief Operating Officer of MEDITECH, and while much of his responsibility revolves around the non-technical side of the business, he keeps his hand in programming and still loves it.

Howard recognized what a central role MIT had played not only in his own life but in the science and technology life of the world, so he and his wife Colleen had always made modest contributions to MIT. They were, however, somewhat put-off by the large size of MIT’s endowment and the amount of money it collects annually. “We weren’t sure,” commented the Messings, “how our contribution could make a real difference.”

Then about six years ago, the Messings attended a Physics Department event held in honor of Neil Pappalardo. “We became hooked! There was, and is, so much passion and enthusiasm. It’s inspiring to see people being able to accomplish their dreams.” Colleen continues, “With so much negativity in the world, the pursuit of this kind of knowledge for its own sake strikes me as grounding for all, connecting us to the world we live in.”
When the Department asked Howard and Colleen to join the newly-formed Patrons of Physics Fellows, their answer was an immediate and enthusiastic "Yes!" They point out that, "Unlike departments in Engineering, the Physics Department has far less ability to secure funds from outside sources and industry. We saw that if we contributed, our gift really could make a difference, especially in the lives of these young and energetic graduate students."

Howard and Colleen look forward to attending department-sponsored talks and chatting with faculty, postdocs, and students. "Even if we can only understand part of what is being said, it still gives us some insight and makes us feel in some small way a part of the 'voyage of discovery.'"

SUPPORT THE MIT DEPARTMENT OF PHYSICS

The MIT Department of Physics strives to be at the forefront in every field where new physics can be found. By constantly pushing the limits, we have a chance to observe new general principles and to test theories of the structure and behavior of matter and energy. We invite you to join us on this journey with your financial support. Please consider a gift on behalf of the MIT Department of Physics. As important as outright gifts are to the Department, deferred gifts and other tax planning approaches can often make a more substantial gift possible. Gifts in any amount to the Physics Department unrestricted fund provide the discretionary funds necessary to start new experiments and new science.

Attracting the best graduate students to work with our faculty continues to be our highest priority. We have established the Patrons of Physics Fellows to recognize friends of the Department who have made it possible for us to recruit the very best graduate students. With your help, we will continue to understand the deepest aspects of nature, perhaps even the origins of space, time, and matter. To make a gift, or for more information on making a gift, please contact:

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You may also make a gift by going directly to the MIT web site at giving.mit.edu, and selecting “Give Now,” then “Schools and Departments,” then “Physics,” to reach one of the Physics Department Funds listed below:

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Helen Young SM 1965, PhD 1968
Minerva and Roberto Zamora
Alireza Zarringhalam PhD 1979
Andrew Zeger SB 1961
Zhibo Zhang PhD 1999
Bing Zhou PhD 1987
Myron Zimmerman PhD 1979
Sidney Zimmerman SM 1955