Welcome from the Department Chair

Dear UC Davis Physics Community,

What a fantastic time to be doing physics! Since my last Welcome Letter we have discovered the Higgs Boson, a momentous event in the history of physics (and one in which UC Davis Physicists played a major role, see our Higgs article). In our Research Highlights article, you can learn about major developments in many fields: Our condensed matter group has produced important advances in our fundamental understanding of magnetism in exotic materials and phase transitions of electrons in solids. Our cosmology group has achieved new insights into the nature of dark matter and cosmic inflation, as well as bringing us a huge step closer to making the next great telescope a reality. Environmental physicists traced the origin of deadly pollutants in the southern San Joaquin Valley and heavy ion physicists probed the nature of the quark-gluon plasma.

Professor and Department Chair Andreas Albrecht

With so many exciting developments it is no wonder that growing numbers of students choose to study physics at all levels, a national trend that is robustly reflected in our own growing program (which is growing even faster than the national rate). We invite all of you to share in the excitement by coming to one of our upcoming events and public lectures hosted by the department.

We are grateful to see our nation and most certainly the state of California emerging from the Great Recession. Improvements in the economy along with the passage of Prop. 30 may stabilize UC's financial situation. Our department is coming out of this difficult period on a great trajectory, with a steadily growing reputation and stature (for example, as measured by extramural funding, we have enjoyed very impressive growth throughout these difficult years). We are also very grateful for our increasingly successful program of private donations that is crucial to our future success. We are fortunate to have a new faculty search underway this year, from which we expect to hire an impressive new member of our high energy experiment group, keeping us on track for our goal of being ranked in the top 20 of physics departments by 2020. We also note the retirement of Professors Kiskis, Klein and Pines, and also our gratitude that all three remain very active and involved in our department.

Still, major challenges face the world of higher education. The growth of higher education costs and mounting student debt are bringing new levels of scrutiny of our costs and efficiency, and of the value of the education we provide. In a century marked with rapid changes to societies and economies and an ever-increasing emphasis on science and technology I am confident that a physics degree is more valuable than ever. I am also confident that our great department has talent and energy to thrive and evolve into something even better than we are today. As physicists we pride ourselves in readily facing up to and flourishing in challenging situations, a reason physics graduates accomplish all kinds of great things and yet another reason to study physics!

Best Regards,

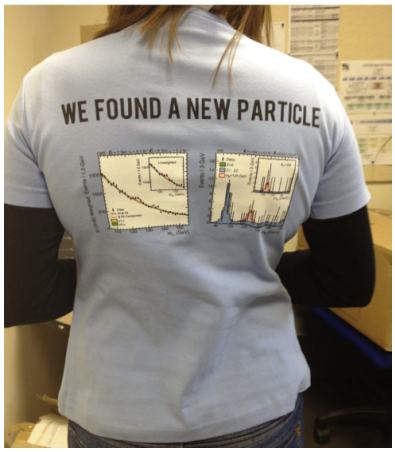
Andreas Albrecht

Professor and Chair

Higgs!

The Higgs boson discovery this summer drew a lot of press attention world wide. That was true at UC Davis as well. You can find UC Davis Dateline coverage of the Higgs discovery, including videos of UC Davis high energy physicists, here.

Professor Mulhearn has provided us with the following summary of the discovery and an explanation of the role of UC Davis Physics in this decades-long quest.



Over the last half of a century, experimental and theoretical physicists have worked together to develop and test the most predictive and successful theory of subatomic particles to date: the Standard Model of particle physics. After an unprecedented effort from thousands of physicists and engineers who built, operated, and analyzed the largest experiment ever built, the CMS and ATLAS collaborations reported the discovery of a new particle on July 4, 2012. The new particle is the quantum fluctuation of the Higgs field, the most exotic component of hte standard model. The Higgs field permeates all of space and leads to spontaneous symmetry breaking, the mathematical explanation for why the weak force is indeed weak compared to the electromagnetic force. The weakness occurs by virtue of the carriers of the weak force acquiring large mass. In the Standard Model, the Higgs field serves a dual purpose, as it also provides the mathematical basis for fundamental fermions, such as quarks and electrons, to have intrinsic mass. Observation of the Higgs boson is (the only possible) direct evidence for the existence of the Higgs field and thus a crucial test of this component of the standard model.

UC Davis has played a major role in the decades-long search for the Higgs boson. To start, Prof. Gunion literally wrote the book: as co-author of "The Higgs Hunter's Guide" in the 1980's he laid out a detailed plan for detecting the unique signature of the Higgs boson using collider experiments. His ideas helped shape the design of the very CMS and ATLAS detectors which ultimately discovered a new boson. Profs. Richard Lander and Winston Ko along with Dr. Richard Breedon recognized the potential in the newly conceived Large Hadron Collider (LHC) and signed the original letter of intent which was the rst step in making the CMS experiment a reality. Profs. Mani Tripathi and Robin Erbacher helped build the largest component of CMS: the muon detector. Profs. Maxwell Chertok and John Conway helped build the smallest, most precice, component of CMS: the silicon tracking detector. The latest addition to the team, Prof. Michael Mulhearn, has turned his attention to the fastest component of CMS: the trigger electronics.

The Higgs boson is the last fundamental particle predicted by the Standard Model: all of the other particles have already been discovered. So far, every experimental test devised for the Standard Model has validated its predictions. Prof. Conway has long championed the cause of measuring the precise properties of a newly discovered boson, and his efforts at measuring its decay into tau leptons is now adding to the evidence that we have indeed found the Higgs. Prof. Mulhearn searched for decays into bottom quarks, which recently resulted in the Tevatron collider adding additional evidence.

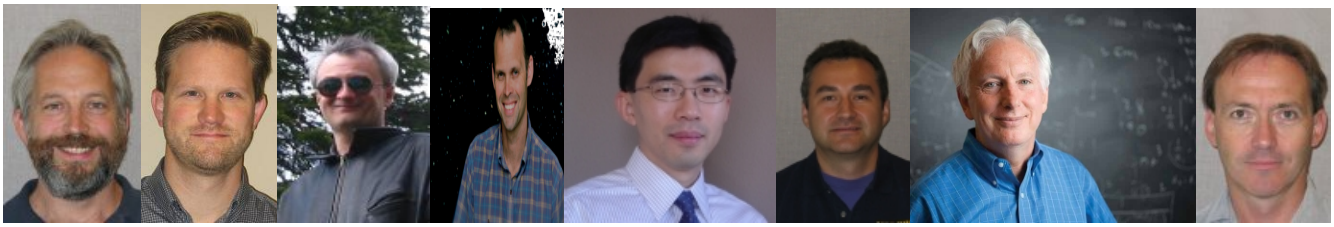
The discovery of what appears to be a Higgs boson completes our picture of the Standard Model, and it might seem that the last chapter is now being written. But for all its success, particle physicists are certain the Standard Model cannot be the end of the story, and now is our best chance to discover the new theory which supersedes it. Profs. Markus Luty and John Terning have helped develop the theory and phenomenology of a leading contender for this new theory: Supersymmetry (SUSY). Prof. Maxwell Chertok is searching for experimental

signatures of the Higgs boson that could result from SUSY. Professor Gunion has recently published several papers dealing with the nature of the Higgs-like state observed at CERN, focusing in particular on the possibility that it is just one of many Higgs bosons or that the observed resonance is actually a superposition of several (unresolved) Higgs bosons. We don't know what nature has in store for us, but the UC Davis team will continue to push both theory and experiment toward a deeper undertanding of fundamental particles.

Prizes and Awards

Our distinguished faculty became even more distinguished over the past year garnering many new honors.

To begin, we ranked 2nd this year (together with Harvard, MIT and FSU) in the number of faculty members elected as Fellows of the American Physical Society in 2012. Congratulations to Professors Cox, Curro, Kaloper, Knox, Liu, Savrasov, Svoboda and Zimanyi pictured below. The criterion for election is exceptional contributions to the physics enterprise.



Other Fellowships awarded include an Insitute of Nanotechnology Fellowhsip for Professor Liu and a UC Davis Hellman Fellowship for Professor Bradac.

Visiting Professorships include a Leverhulme Trust Visiting Professorship for Professor Kaloper and a Senior Visiting Professorship for Professor Charles Fadley. Professor Fadley's award was from the French national program to promote world-class laboratories in physics (*Laboratoires d'Excellence: Physique: Atomes, Lumiere, Matiere--PALM*). Professor Pickett has Visiting Professorships this academic year at Hong Kong Baptist Uinversity and at the National University of Singapore.

Professor Fadley was also selected as one of the first three recipients of the status of Fellow of Elettra, the Italian national synchrotron radiation and free electron laser facility. The laudatio reads in part, "Professor Charles S. Fadley is a distinguished solid state physicist and materials scientist who has given fundamental contributions to the development of photoelectron spectroscopy, diffraction and holography worldwide...."

Professor Picket was also named the Simmons Foundation Fellow in Theoretical Physics for 2012-13.

Professor David Pines was named by the AAPT as the 2012 John David Jackson Excellence in Graduate Physics Education Awardee.

Professor John Rundle and his team received the NASA Software of the Year award.

Professor Nick Curro won the honor of Chancellor's Fellow.

Professor Gergely Zimanyi won the 2011-2012 UC Davis Distinguished Teaching Award for Undergraduate Teaching.

Professor Kiskis won the Charles P. Nash Prize awarded by the Davis Faculty Association, Davis Division of the Academic Senate, and UC Davis Academic Federation for exceptional efforts in advocating for shared governance and faculty interests and welfare.

Professor Tyson was honored with the 2012 Hintze Lectureship at Oxford University.

Research Highlights

The reputation of our department continues to grow, in large part due to the research conducted here and the impact it has on other scholars around the world. Here we collect a few highlights of the research results achieved in the past year, representing a small fraction of our total research productivity.

Condensed Matter Physics

1) The condensed matter nuclear magnetic resonance group led by Nicholas Curro recently published an article in the Proceedings of the National Academy of Sciences. (*http://arxiv.org/abs/1206.1879*). Using detailed temperature and orientational dependent studies of the NMR Knight shift of single crystals, the group was able to investigate the interplay between the local and itinerant degrees of freedom of several different heavy fermion compounds. The paper was published side-by-side with a theoretical paper led by David Pines (*http://arxiv.org/abs/1206.1115*), and in collaboration with former UC Davis postdoc Yifeng Yang (now at the Institute of Physics in Beijing.) Together these two papers advance our general understanding of the Kondo lattice phase diagram, and shed light on the relationship between long range ordered states and the emergence of a heavy electron fluid. Davd Pines writes regarding the second paper, "we introduce the concept of hybridization effectiveness and show it is the organizing principle that determines whether the ground state is a local moment antiferromagnet, an unconventional superconductor, or, in some cases, both.

2) Warren Pickett, together with graduate student Yundi Quan and his former postdoc Victor Pardo made a discovery that raises fundamental questions about phase transitions in the movement of electrons in solids, as reported in Phys. Rev. Lett. 109, 216401 (2012), and also available here. Using first principles (i.e. parameter-free, model-independent) calculations of the quantum mechanical states, this three-person team has discovered that in several metal-insulator transitions that have been understood as charge-order transitions, there is (to high accuracy) no charge order; i.e., the charges are distributed evenly among the atoms. Substantial changes in the structure and various microscopic characteristics of the materials do change, but without the variation of charge that has been believed to cause these transitions. Their work begins the re-examination of the underlying basic quantum processes that will reveal the actual mechanism of these striking changes between quantum phases in solids, which will also bear directly on the basic chemical concepts of "formal valence" and "oxidation state."

Cosmology

1) Three different groups of UC Davis researchers had remarkable findings in the past year about the nature of dark matter as revealed by galaxy cluster collisions. Graduate student Will Dawson, his adviser David Wittman, and a cast of others discovered a merging cluster of galaxies in which the collisionless dark matter and galaxies have separated from the collisional gas which constitutes most of the baryonic mass of any cluster. This "dissociation" allowed the group to put an upper limit on the self-interaction cross-section of dark matter, which they hope to tighten with further data. For more, visit this post on Will Dawson's blog.

Meanwhile, postdoc James Jee first-authored a surprising paper this spring that hints at non-gravitational self interactions for dark matter. See NPR coverage of this work here, or read the paper here.

Professor Bradac also had something to say on the subject, writing, "with new and better data for the cluster A520 we have once again measured the properties of dark matter and have confirmed that (excluding gravity) dark matter interacts very little (if at all) with itself." You can read about her work in "On Dark Peaks and Missing Mass: A Weak Lensing Mass Reconstruction of the Merging Cluster System Abell 520."

2) UC Davis postdoc Zhen Hou, graduate students Brent Follin and Marius Millea and Professor Lloyd Knox, together with their South Pole Telescope teammates, recently sharpened up constraints on models of early Universe inflation, as covered in this Cosmic Variance blog post.

3) Professor Tyson is the director of the planned Large Synoptic Survey Telescope (LSST) which was given top ranking in last year's Decadal Review, as described in last year's Newsletter article. This July the National Science Board gave approval for the National Science Foundation to advance LSST to the final design stage. Read more about this critical project milestone here.

4) Professor Bradac and collaborators observed a source so distant that they are seeing it as it was when the Universe was less than 10% of its current age. To date, this is the faintest galaxy with a successfully measured spectrum. The discovery is important because other similar observations of similarly distant galaxies use unusual objects that are not representative. These observations are helping us answer questions of how the first galaxies formed and how they transformed the Universe from a highly opaque state to transperent by clearing out the cosmic fog and starting the cosmic dawn. This work was reported in Spectroscopic Confirmation of a z = 6.740 Galaxy behind the Bullet Cluster.

Environmental Physics

Professor Cahill completed his 14-year effort to understand the sharply enhanced death rate in the southern San Joaquin Valley with work published as two articles in a special EPA-sponsored ten-article issue of Aerosol Science and Technology. He used the synchrotron X-ray Fluorescence capabilities of the LBNL Advanced Light source to establish the hard-to-measure ambient air content of very fine (0.26 um > Dp > 0.09 um) and ultra fine (< 0.09 micrometer diameter) particles in the air of the California Central Valley, Redding to Bakersfield. When these data were merged with the excellent California data on mortality, the long-suspected link between ultra fine insoluble particles and ischemic heart disease deaths was established, showing a 60% enhancement in the southern San Joaquin Valley. Through the compositional analyses, the sources were identified - debris from brake drums and pads, and zinc in lubricating oil, especially from heavy trucks.

Heavy Ion Physics

The Relativistic Heavy Ion group led by Manuel Calderón de la Barca Sánchez and Daniel Cebra has been making news in the study of bottom quarks in a hot Quark Gluon Plasma. Graduate student Guillermo Breto Rangel was one of the lead authors in a paper published in Physical Review Letters by the CMS collaboration on the study of Upsilon mesons, a bound state of a bottom quark and a bottom anti-quark, in Pb-Pb collisions at the LHC (http://prl.aps.org/abstract/PRL/v109/i22/e222301). The paper discusses the first observation of sequential suppression of the Upsilon states, in order of their binding energy. This observation was predicted over a decade ago and the effect has now been confirmed experimentally. This observation is important in establishing that the system produced in heavy ion collisions is made of deconfined quarks and gluons, as expected for a Quark Gluon Plasma. The details of the suppression pattern can be used as a way to infer the temperature of the Quark Gluon Plasma, which is estimated to be about 500 MeV (over 5 orders of magnitude hotter than the sun's core). An accompanying article discussing the importance of this result written by Ramona Vogt, an adjunct professor in the department, appeared in APS "Physics" (http://physics.aps.org/articles/v5/132).

High Energy Physics

Of course there was big news in the high energy physics community with the July 4, 2012 discovery of the Higgs. See the article by Professor Mulhearn elsewhere in this Newsletter about the significant UC Davis role in that discovery. As a sample of other work by the high energy group, we note that Professors Chertok and Gunion published in Physical Review Letters their results on what the CERN data are telling us about the Higgs sector and super symmetry.

The next-to-minimal supersymmetric model in particle physics predicts light pseudoscalar Higgs bosons. Chertok and Gunion led a search using data taken with the CMS detector at the LHC for such a Higgs with decays to muon pairs. Although the analysis clearly showed the production of the Upsilon mesons, no Higgs signal was observed, and world's-best constraints on this model were extracted.

Events

Professor Albrecht at TEDxUCDavis

The always-popular Picnic Day Physics Show

On Picnic Day 2013 we will have an alumni reception, a series of public lectures and the always-popular Physics Show. Keep an eye out for other physics department events as well, such as public lectures. We have one scheduled already: Sean Carroll will speak in the evening of Wednesday May 22nd at the UC Davis Conference Center. Sean is a very entertaining and compelling public speaker and the author of two books, "From Eternity to Here: The Quest for the Ultimate Theory of Time" and "The Particle at the End of the Universe: How the Hunt for the Higgs Boson Leads Us to the Edge of a New World." More details will be available on our department web pages closer to the date. Dr. Carroll's presentation will be in the middle of the week of the "Cosmic Frontiers Conferences" at UC Davis that will bring cosmologists from around the world to discuss the latest ideas and latest data, most notably from the Planck satellite launched in 2009 whose first cosmological results will be out in March.

In the previous year we had well-attended and fascinating public lectures from Professor Lisa Randall, hosted by HEFTI, and Department Chair Andreas Albrecht at TEDxUCDavis. Albrecht's 12-minute TEDx talk is available here and well worth checking out. Our Picnic Day 2012 public lectures were, "The Higgs Boson: A Tale of Two Cities," "The Multiverse," "Dark Energy and Dark Matter" and "Infinity in Mathematics and Physics." We also sponsored, with others at the University, "A Conversation on Creativity." This interdisciplinary event featured Physics Nobel Laureate Martin Perl and his son *The New Republic*'s art critic Jed Perl discussing the creative process in the sciences and the arts.

We had a special visit from Chancellor Katehi who wanted to tour Professor Mani Tripathi's "Facility for Interconnect Technologies," for three-dimensional integration of electronics. Professor Tripathi told us, "The Chancellor is deeply interested in the subject of 3-D integration, having worked in this field herself, and appreciated the work we are doing for the upgrade of the CMS detector [one of the two big detectors at CERN used for this past summer's Higgs discovery]. She even sat down and learned to operate some of our bonding equipment."

The Chancellor bonding with Physics

The physics department is not only engaged in physics, but also in fighting hunger in Yolo County. With participation from students, staff and faculty we field a team of nineteen for the fourth annual

Team Physics before the Running of the Turkeys

Running of the Turkeys, a 5k run on Thanksgiving morning to benefit the Food Bank of Yolo County (FBYC). We took 2nd place in the largest team entry category! Altogether we raised almost $1,000 for the FBYC (via donations and entry fees) and had a fabulous time doing it.

Noteworthy New Courses

Our faculty members continue to innovate not just in research, but in our course offerings too. We bring you news of two of our new courses here. Professor Marusa Bradac has a new general education course, taught last year for the first time, called "The Physics of California." Professor John Rundle is creating the department's first foray into "econophysics" with his course of the same name available as an upper division undergraduate and graduate course to be taught this winter.

The Physics of California

Professor Bradac has blended her love of living in California and physics into this new general education course. As its name suggests the course is organized around phenomena students experience while living in California. The syllabus includes: Physics of Surfing, Skiing, and Scuba Diving, Oceanography, Seismology, Climate Change, Weather Forecasting and Global Warming and other topics. The course addresses questions such as why do we have to worry about earthquakes? Why can we surf and ski in the same day? What enables skiiing, what allows us to turn, what makes our skis go fast? Why can we scuba dive and why do they always tell us not to hold our breath? Why is surfing in California better in winter than it is in the summer? And why do waves push us forward making surfing such a fun experience in the first place?

Taught for the first time in the 2011-2012 school year, Professor Bradac appears to be succeeding in passing on her love of physics to non-science majors. Student comments include, "...having never taken physics before, I am now much more interested in the overall subject" and "Great topic, great professor. Thank you for such an enjoyable experience."

Econophysics

Econophysics is the application of ideas from statistical mechanics to the financial markets. Markets are complex self-adapting systems that are observed to undergo sudden transitions such as “booms” or “bubbles” and “busts” or “crashes”. Transitions in system dynamics are associated with the nucleation and growth of fluctuations, together with a threshold in the state space of the system. Models of phase transitions, such as those used for thermal and magnetic systems, are important for use in understanding complex market dynamics. Markets are also observed to obey scaling dynamics, an interesting example being the existence of the Pareto distribution of wealth among populations.

In Professor Rundle's course the dynamics of markets will be introduced from a physics and systems perspective. Models for first and second order phase transitions will be described and used to construct simple models for the markets. Discussion topics will include the statistical distributions of returns, the phase dynamics of prices, and models for the markets. Specific markets will also be analyzed, including the equity stock markets (NYSE/Euronext, NASDAQ),

the fixed income (bond) markets (Government and Municipals), and the commodities markets (CME and Futures). Professor Rundle will also introduce time-dependent models for equity valuations such as the Black-Scholes equation that are used in options pricing. Students will be expected to contribute actively to discussions, as well as complete a project using financial data and analysis.

Alumni Seminar Series

This spring, like we have done every spring since 2007, we held our alumni seminar series as a one-unit course for our undergraduate and graduate students. This course is very valuable for our current students because our alumni give a perspective that the faculty cannot provide. And for me, as a physics teacher, it is always gratifying to hear our alumni refer to the benefits they see of their time spent hard at work here studying physics. It is also heart warming to see them respond to this opportunity to give back to the department.

Over the past few years we have heard several themes come out repeatedly from our alumni:

1) In many circles, a physics degree leads to instant respect for the intelligence of the degree-holder.

2) Pursuing a physics degree is good practice for tackling a variety of problems – even ones that have nothing to do with physics.

3) Training in physics somehow helps one to have a systems-level view of an organization, market, or complex product, which allows one to see connections that others miss.

4) Physicists can find solutions to complex problems, even outside their area of expertise.

We also hear repeatedly about things that have nothing to do with physics, such as the importance of networking, good communication skills, and doing things that you love doing. These are useful bits of wisdom for our students to be hearing first hand from those working outside of academia, who were once where they are now.

Yatish Mishra

We thank this year's participants for their enthusiastic response to our request; their time spent preparing and the time and expense of traveling to and from campus. They did this for nothing in return, other than the opportunity to tell their story to our current students.

They were Carol Eidt (BS 1977, Partner Software Developer, Microsoft), Alan Wong (BS 1996, Former Staff Technologist and Engineering Group Leader at Intel Corporation), Brian Fies (BA 1983, Freelance Writer), Yatish Mishra (BS 1986, President & CEO RagingWire Data Centers), Marusa Bradac (physics professor at UC Davis), and Michael Lazich (BS 1985, Harvestmark).

If you would like to give a presentation, please register here.

--Lloyd Knox

Private Support for the Department of Physics

The Department of Physics has grown and changed tremendously in recent years. We are growing in quantity and quality by many measures such as student enrollments and extramural research funding. According to US News & World Report our graduate program moved from 44th to 29th between 2002 to 26th in 2010 (their most recent ranking). This unprecedented rise is one we are committed to continue.

Looking toward the future, we have an expanded vision of what our department can hope to become. We intend to further improve our ability to attract the highest quality people to our institution, as faculty members, postdoctoral scholars and graduate and undergraduate students. We thus can achieve even higher levels of scientific productivity and leadership. We want to bring our instruction to a higher level of excellence. We want to make our physical environment one conducive to the sharing of ideas, thereby facilitating new discoveries. We aspire to become one of the elite physics departments of the world.

To reach these goals we are relying on both public and private support. Donations will support our core activities in ways that state and federal funds cannot, and allow us to compete with the very best departments, all of which can count on private support to maintain and enhance their programs.

We are very grateful for the support from alumni, parents, foundations, corporations, faculty, staff and friends of physics. The amounts are substantial, totaling over $2 million dollars in the past 3 years.

Even donations that would be a small fraction of $2 million can make a big difference. The majority of our donations are targeted for specific research programs. Perhaps you would like to contribute to a graduate fellowship, instructional laboratory upgrades, or the renovation of our atrium. Perhaps you would like to provide an unrestricted gift. Such gifts allow us to capitalize on emerging opportunities, and to direct funds to where they are needed most.

If you are interested in helping us reach our goals, please see our Giving to Physics page. You may also wish to contact Department of Physics Chairman Andreas Albrecht at (530) 752-5989 (ajalbrecht@ucdavis.edu) or Director of Development for the College of Letters and Sciences Shari Kawelo via email at sekawelo@ucdavis.edu or by phone at (530) 754-2225.