Spring 2014

DIMENSIONS

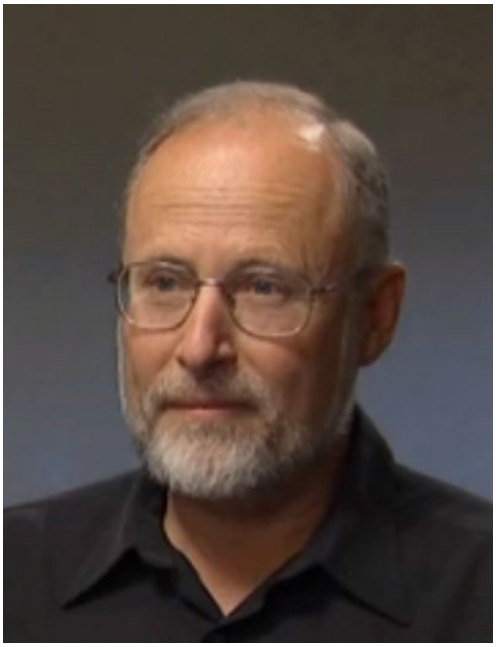
Department of Physics & Astronomy

Float-zone refining and crystal growth of UPt_3 in ultra-high vacuum at 1760 °C

IN THIS ISSUE:

Twists of Nature: chirality and complex symmetry breaking

by William P. Halperin



At the forefront in condensed matter physics is the investigation of quantum states that break symmetry, often discovered serendipitously on cooling materials to ever lower temperatures. Good examples are superconductors and superfluids, which by their nature break gauge symmetry, exhibiting frictionless flow, and whose unusual properties have been of continuing interest since the discovery of superconductivity in 1911 by Kamerlingh Onnes.

There was a paradigm shift in 1971 with the observations of superfluidity in liquid helium-three, the light isotope of helium which is a fermion. This superfluid was discovered by Osheroff, Richardson and Lee (Nobel 1996) at less than 0.003 K [1] having two thermodynamic phases in zero magnetic field, fortuitously named A and B by graduate student Doug Osheroff. Actually the prediction of this superfluid by Anderson and Morel (A-phase) and by Balian and Werthamer (B-phase) came 12 years before, including the expectation for additional broken symmetries beyond gauge symmetry. These superfluids are quantum states with non-zero orbital angular momentum (L=1) and spin angular momentum (S=1), with the A-phase breaking time reversal symmetry and separately breaking rotational symmetry of orbital and spin coordinates, and exhibiting chiral symmetry, like that of a left or right-hand screw. The theoretical interpretation of NMR frequency shifts that were the "smoking gun" for this unique spin-triplet, *p*-wave superfluid was made by Tony Leggett (Nobel 2003). In the B-phase the characteristic broken symmetry is a relative symmetry, specifically the relative orientation between spin and orbital coordinates of the Cooper pairs that form the superfluid condensate. Direct observations of broken relative symmetries can be difficult to demonstrate. So it is worth noting that the broken relative symmetry of the B-phase was first established directly through the discovery of the Faraday rotation by a magnetic field of the polarization of propagating transverse mass currents, i.e. "transverse sound". This acoustic Faraday effect was predicted by Moores and Sauls in 1993 [2] and is analogous to the discovery of this effect for light by Michael Faraday in 1845. And it was observed by Lee *et al*. in 1999 [3] where both theory and experiment were done at Northwestern. In the case of ^{3}He-A, a defining broken symmetry of this phase is that of time-reversal. Although signatures of broken time-reversal symmetry in ^{3}He-A have been discussed for over 40 years, direct observation of broken time reversal symmetry of the A-phase, was only accomplished recently in beautiful experiments in 2013 by a group lead by Kimitoshi Kono [4], our Heilborn speaker two years ago. Today, ^{3}He research has evolved at Northwestern with discovery of new quantum phases [5] characterized by additional broken symmetries imposed by spatial confinement of the superfluid imbibed into highly porous silica aerogel, and in small pores and slabs.

The story of similar discoveries of broken symmetry in condensed phases of electrons, that is to say unconventional superconductors, is equally remarkable. Most notable are the high transition temperature (high T_c) cuprate "*d*-wave" superconductors (L=2, S=0), which in addition to gauge symmetry, break orbital rotation symmetry. In a world-wide effort literally hundreds of compounds have been found to be in this class, the first of which was discovered in 1986 by Bednorz and Müller (Nobel 1987). In another class of compounds, the "heavy fermion" metals, there is evidence that

the superconducting states break additional space-group symmetries, including broken time-reversal symmetry. They are known as "heavy" because the mass of the conduction electron is ~ 100 times the bare mass of an electron in vacuum. The most important examples are compounds of uranium or cerium including UPt_3, URu_2Si_2, and $CeCoIn_5$, and a compound similar to the cuprates, Sr_2RuO_4. Combinations of broken space-group symmetries, combined with broken time reversal, may exhibit chiral symmetry as in superfluid ^{3}He-A. Such quantum states are topologically non-trivial and the subject of considerable current interest in condensed matter physics [6]. But there are only two superconducting compounds in either of these two classes which are thought to be candidates. They are UPt_3 and Sr_2RuO_4 and so I will turn my discussion to the more promising of the two, UPt_3.

Superconductivity in UPt_3 at 0.5 K was discovered by Stewart *et al*. at Los Alamos in 1984 [7] two years before the explosion of research on high T_c superconductors. The key discovery in this compound was its multiple component phase diagram which placed this material in the same category as superfluid ^{3}He. This came in large measure from specific heat experiments, performed in zero magnetic field by Fisher *et al*. in 1989 [8], and the identification of the magnetic field-temperature phase diagram from acoustic experiments by Adenwalla *et al*. in 1990 [9], the latter being a Northwestern collaboration. The very existence of three thermodynamic phases provided convincing evidence that the superconducting quantum state must have a number of degrees of freedom and that there must be broken symmetries beyond gauge symmetry. With the rush of experiments that followed, various theoretical models were proposed including a mixed representation model from Chen and Garg, a proposal for E_{1g} symmetry with (L=2, S=0) by Park and Joynt at UW-Madison, and the proposal by Sauls of a (L=3, S=1) E_{2u} state. Although the preponderance of experiment since then concurs with Sauls' predictions [10], a consensus view had not emerged until recently. The motivation to provide direct experimental evidence to correctly describe the symmetry of the superconducting state has come in part from increasing interest in topological superconductivity [11]. Both the E_{1g} and E_{2u} states have chiral thermodynamic phases with topological character. In contrast a very recent proposal for an E_{1u} state based on NMR and thermal conductivity experiments does not. So how to resolve this puzzle? An important factor for UPt_3 has been improvement in sample quality.

Some years ago David Seidman, Materials Science and Engineering at Northwestern, and myself, with support from our local Materials Research Center and the NSF, constructed a crystal growth facility dedicated to UPt_3. The unique techniques we chose - ultra-high-vacuum, electron-beam, float-zone refining and crystal growth - were quite successful (see the image on the front cover). We were able to produce substantially larger, higher quality, and purer crystals of this compound than had been previously possible anywhere. Among a number of projects, there are several important recent experiments with these high quality crystals that bear on clarification of the symmetry of the superconducting state. In the first, Van Harlingen's group at the University of Illinois performed tunneling experiments that are sensitive to the phase of the superconducting state, showing that there was phase winding of the order parameter of 2. And in a second experiment they measured the energy gap nodal structure [12]. Both results are uniquely consistent with E_{2u} symmetry. A second recent result comes from the Stanford group of Kapitulnik who discovered that just one of the thermodynamic phases of UPt_3 exhibits Kerr rotation of the polarization of light reflected from its surface, demonstrating that the superconducting state breaks time reversal symmetry [13]. These two landmark efforts precisely confirm the prediction by Jim Sauls in 1994 that indeed UPt_3 is a chiral superconductor.

It is literally a twist of Nature that the quantum phases of two materials composed of the lightest and the heaviest of elements break both gauge and time-reversal symmetries, and share a common chiral symmetry.

1. Evidence for a new phase of solid He-3, D.D. Osheroff, R.C. Richardson, and D.M. Lee, Phys. Rev. Lett., **28**, 885 (1972).
2. Transverse waves in superfluid ^{3}He-B, G.F. Moores and J.A. Sauls, J. Low Temp. Phys., **91**, 13 (1993).

3. Discovery of the acoustic Faraday effect in superfluid ^{3}He-B, Y. Lee, T. Haard, W.P. Halperin, and J.A. Sauls, Nature, **400**, 431 (1999).
4. Chiral symmetry breaking in superfluid ^{3}He-A, H. Ikegami, Y. Tsutsumi, and K. Kono, Science, **341**, 59 (2013).
5. New chiral phases of superfluid ^{3}He stabilized by anisotropic silica aerogel, J. Pollanen, J.I.A. Li, C.A. Collett, W.J. Gannon, W.P. Halperin and J.A. Sauls, Nature Physics **8,** 317 (2012); The superfluid glass phase of ^{3}He-A, J.I.A. Li, J. Pollanen, A.M. Zimmerman, C.A. Collett, W.J. Gannon, W.P. Halperin, Nature Physics **9,** 775 (2013).
6. Topological insulators and superconductors: tenfold way and dimensional hierarchy, S. Ryu, A.P. Schnyder, A. Furusaki and A.W.W. Ludwig, New Jour. Phys., **12**, 065010 (2010).
7. Possibility of coexistence of bulk superconductivity and spin fluctuations in UPt_3, G. Stewart, Z. Fisk, J. Willis, and J.L. Smith, Phys. Rev. Lett., **52**, 679 (1984).
8. Specific heat of UPt_3: evidence for unconventional superconductivity, R.A. Fisher, S. Kim, B.F. Woodfield, N.E. Phillips, L. Taillefer, K. Hasselbach, J. Flouquet, A.L. Giorgi, and J.L. Smith, Phys. Rev. Lett. **62**, 1411 (1989).
9. Phase diagram of UPt_3 from ultrasonic velocity measurements, S. Adenwalla, S.W. Lin, Q.Z. Ran, Z. Zhao, J.B. Ketterson, J.A. Sauls, L. Taillefer, D.G. Hinks, M. Levy, and B.K. Sarma, Phys. Rev. Lett. **65**, 2298 (1990).
10. The order parameter for the superconducting phases of UPt_3, J.A. Sauls, Adv. Phys. **43**, 113 (1994).
11. Non-Abelian anyons and topological quantum computation, C. Nayak, S.H. Simon, A. Stern, M. Freedman, and S. Das Sarma, Rev. Mod. Phys., **80**, 1083 (2008).
12. The transition between real and complex superconducting order parameter phases in UPt_3, J.D. Strand, D.J. Bahr, D.J. Van Harlingen, J.P. Davis, W.J. Gannon, W.P. Halperin, Science, **328**, 1368 (2010); Evidence for complex superconducting order parameter symmetry in the low temperature phase of UPt_3 from Josephson interferometry, J.D. Strand, D.J. Van Harlingen, J.B. Kycia, and W.P. Halperin, Phys. Rev. Lett., **103**, 197002 (2009).
13. Observation of broken time-reversal symmetry in the B-phase of the heavy fermion superconductor UPt_3, E.R. Schemm, W.J. Gannon, C. Wishne, W.P. Halperin, and A. Kapitulnik, Science, to appear.

Faculty News

Eric Dahl and Nate Stern have been selected for the prestigious Early Career Research Program by the U.S. Department of Energy (DOE). Eric Dahl will use the award to build novel instruments for the detection of particle dark matter, and Nate Stern will use the award to investigate quantum phenomena in two-dimensional materials. P&A faculty represent two of the 35 total awards selected by DOE this year to support and stimulate the research programs of outstanding scientists early in their career.

William Halperin was elected Vice-Chair of the Division of Condensed Matter Physics (DCMP) and will serve four years at Vice-Chair (2014), Chair-Elect (2015), Chair (2016) and Past Chair (2017). The DCMP is the largest division of the American Physical Society, representing research areas ranging from solid-state physics, quantum liquids and solids, to soft matter. Research in Condensed Matter Physics concentrates on such topics as superconductivity, semi-conductors, magnetism, complex fluids, and thin films.

This discipline covers a broad range of research in both basic and applied physics. The Chair of DCMP oversees the March Meeting of the APS, which attracts approximately 10,000 physicists from all over the world from industry, universities, and major laboratories, and is the largest physics meeting in the world.

Shane Larson presented "Pluto's Day of Reckoning" at Northwestern's TEDx event, which was held on April 12, 2014. Professor Larson holds a joint appointment between the NU Department of Physics and Astronomy and the Department of Astronomy at Adler Planetarium.
Read the full article at:
http://www.northwestern.edu/newscenter/stories/2014/02/tedx-northwestern-april-12.html?utm_campaign

Yoram Lithwick and student Sam Hadden found many small exoplanets are covered in gas. Professor Lithwick presented results at a January 6 session of the American Astronomical Society demonstrating that 60 exoplanets under investigation are covered in gas. This work greatly expanded our knowledge of sub-Neptune exoplanets, and has been written about by The Economist, New Scientist, National Geographic, and Sky & Telescope.
Read the full article at:
http://www.northwestern.edu/newscenter/stories/2014/01/many-small-exoplanets-found-to-be-covered-in-gas.html

Also, Professor Lithwick's proposal "Planet Formation in the Age of Kepler" has been awarded an NSF Career award, the Foundation's most prestigious awards in support of young faculty.

Adilson Motter's group was featured in the cover story of the January 18 issue of New Scientist. The article elaborates on conditions under which locally deleterious interventions can have globally beneficial effects in a network.
Read the full article:
http://www.newscientist.com/article/mg22129520.600-42nd-st-paradox-cull-the-best-to-make-things-better.html

Also, Professor Motter has been featured among the 30 most promising scientists under the age of 40 born in Latin America. He was born in Brazil, is among the 9 featured scientists currently working in the US. The compilation covers all fields of science, engineering, and mathematics, and is published by a joint collaboration between the Chilean magazine Qué Pasa and the international organization LatinAmericaScience.org
Read the full article:
http://www.quepasa.cl/articulo/ciencia/2014/05/3-14327-9-latinoamerica-genial.shtml

Frank Petriello has been elected co-spokesperson of the CTEQ collaboration. CTEQ is an international community of physicists devoted to a broad program of research and education in high-energy physics centered on Quantum Chromodynamics (QCD).
For more information on the CTEQ collaboration and its activities, read more here:
http://users.phys.psu.edu/~cteq/

James Sauls was the guest of the University of St. Andrews and University of Edinburgh during the month of March 2014 as "Distinguished Lecturer of the Scottish Universities Physics Alliance" and the Higgs Centre for Theoretical Physics, where he spoke on spontaneous symmetry breaking and the detection of Anderson-Higgs modes in superfluid Helium. He was an invited speaker at the Royal Society meeting on "Emergence of new exotic states at interfaces with superconductors" at Chicheley Hall, where he lectured on Majorana fermions in topological superfluids. He also delivered the invited talk on the discovery of broken time-reversal symmetry in the chiral phase of liquid Helium at the workshop on "Topological Protection and Non-Equilibrium States in Strongly Correlated Electron Systems" at St. Andrews University.

Arthur Schmidt has been with the Department of Physics and Astronomy for 30 years! Also, Professor Schmidt has been working with the Society of Physics Students (SPS) giving demonstrations using 3D scanning and printing. Recently, Professor Schmidt visited Eugene Field School in Andersonville, Chicago where he entertained some forty 5th grade students for an hour presentation of Physics demonstrations.

Selected Publications

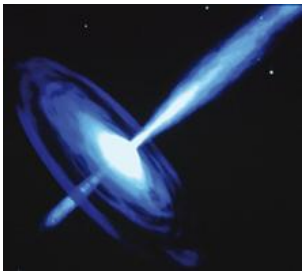
Adilson Motter
Inertial particle trapping in an open vortical flow by J.R. Angilella, R.D. Vilela, and A.E. Motter.
Journal of Fluid Mechanics 744,183 (2014).

This study explains the counterintuitive phenomenon in which heavy particles can be fluid-dynamically trapped in bounded regions of an open fluid flow. The phenomenon is mediated by attractors in the neighborhood of vortex pairs that are analogous to stable Lagrange points in the classical three-body problem, and allows particles denser than the fluid to move simultaneously against the flow and against gravity.
http://dx.doi.org/10.1017/jfm.2014.38

Frederic Rasio
Tidal Dissipation and Obliquity Evolution in Hot Jupiter Systems by Francesca Valsecchi and Fred Rasio **The Astrophysical Journal, 786, 102 (2014)**

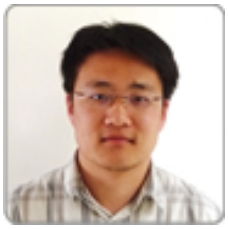
Two formation scenarios have been proposed to explain the tight orbits of hot Jupiters. They could be formed in orbits with a small inclination (with respect to the stellar spin) via disk migration, or in more highly inclined orbits via high-eccentricity migration, where gravitational interactions with a companion and tidal dissipation are at play. Here we target hot Jupiter systems where the misalignment lambda has been inferred observationally and we investigate whether their properties are consistent with high-eccentricity migration. Specifically, we study whether stellar tides can be responsible for the observed distribution of lambda and orbital separations. Improving on previous studies, we use detailed models for each star, thus accounting for how convection (and tidal dissipation) depends on stellar properties. In line with observations suggesting that hotter stars have higher lambda, we find that lambda increases as the amount of stellar surface convection decreases. This trend supports the hypothesis that tides are the mechanism shaping the observed distribution of lambda. Furthermore, we study the past orbital evolution of five representative systems, chosen to cover a variety of temperatures and misalignments. We consider various initial orbital configurations and integrate the equations describing the coupled evolution of the orbital separation, stellar spin, and misalignment.

We account for stellar tides and wind mass loss, stellar evolution, and magnetic braking. We show that the current properties of these five representative systems can be explained naturally, given our current understanding of tidal dissipation and with physically motivated assumptions for the effects driving the orbital evolution. http://iopscience.iop.org/0004-637X/786/2/102/article;jsessionid=4671AE02DFDE4316FEA711AE04468E03.c2



New Research Staff

Rosangela Follmann joined Professor Motter's group as a post-doctoral fellow in March 2014. She was previously a post-doctoral fellow at the School of Engineering of the University of São Paulo, Brazil, and was a visiting scholar in the Motter group for about a year. Her research is focused on network synchronization and structural networks.



Youwei Yao joined CIERA in March 2014 as a new Postdoctoral Associate, working with Professor Mel Ulmer. Yao (as he likes to be called) is from the Changning District of Shanghai, in China, and got his Ph.D. in September 2013 working in Professor Hideyo Kunieda's group at Nagoya University in Japan. There he designed, fabricated, and verified his multilayer coating models. These multilayer coatings have been put on the hard X-ray telescope mirrors to be flown on the Japanese-US Astro-H satellite. Here at Northwestern, he will be working with Professor Mel Ulmer and his group, developing coatings for X-ray mirrors which change shape when magnetic fields are inserted in them ("magnetic smart materials").

Research Staff News

Daryl Haggard, CIERA Postdoctoral Fellow has been closely watching a gas cloud, called G2, near the Milky Way's black hole, called Sgr A*. She discussed her latest data at a press briefing, "Advances in Astrophysics," at the April Meeting of the American Physical Society (APS). The closest approach between the black hole and gas cloud is predicted to occur any day now. Haggard has been using two world-class observatories, the Chandra X-ray Observatory and the Very Large Array, to gather data on this potentially spectacular encounter. At the APS meeting, she also made a presentation, "Hot News from the Milky Way's Central Black Hole," as part of the session "Hot Topics in Astrophysics".

Nick Cowan, Daryl Haggard, CIERA Postdoctoral Fellows have both accepted Assistant Professor positions in the Department of Physics and Astronomy at Amherst College in Amherst, Massachusetts. They will start there in the Fall of 2014. Nick and Daryl are looking forward to building a new astronomy program at Amherst, and exploring the many opportunities in the Five Colleges Astronomy Department.

Nate Kaib, CIERA Postdoctoral Fellow has accepted an Assistant Professor postion in the Department of Physics and Astronomy at the University of Oklahoma, in Norman, Oklahoma. Before moving to his faculty job, Nate will spend a year at the Carnegie Institute, in Washington DC, as a Postdoctoral Fellow. Then, starting in August 2015, Nate will move to the University of Oklahoma, where he looks forward to building a productive research group focused on modelling the formation and evolution of planetary systems.

Sonny Mantry will begin a faculty appointment at the University of North Georgia starting this fall. He was a LHC Theory Intiative fellow based at Northwestern University from 2011 to 2013, and was a postdoctoral researcher in Professor Frank Petriello's group during the previous year. Sonny is theorist working on topics ranging across particle, nuclear and cosmological physics.

Alumni News

Paul Cadden-Zimansky graduated in 2008 with a Ph.D. in Physics under the supervision of Venkat Chandrasekhar. He is now an Assistant Professor of Physics at Bard College. He has worked there since 2012.

Zhigang Jiang graduated in 2005 with a Ph.D. in Physics under the supervision of Venkat Chandrasekhar. He was just tenured at the Georgia Institute of Technology. Also, his research group works in the Quantum Transport and Infrared Spectroscopy Laboratory and they are working on Infrared measurement.

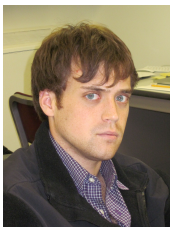
Vaishnavi Rajagopal has accepted a post-doctoral position at Rowland Institute at Harvard University starting in the Fall 2014.

Roberto Vega-Morales who received his doctoral degree Summer 2013 has won the American Physical Society award for best dissertation in theoretical particle physics. Congratulations to Roberto, his advisor Ian Low (and his co-advisor Tim Tait) on this major achievement! Here is the official citation for the award.

"Dr. Roberto Vega-Morales, Northwestern Ph.D. in Physics, 2013, has received the 2014 J.J. and Noriko Sakurai Dissertation Award in Theoretical Particle Physics from the American Physical Society. The Award recognizes exceptional young scientists who have performed original doctoral thesis work of outstanding scientific quality and achievement in the area of theoretical particle physics. The Award consists of $1,500, a certificate citing the accomplishments of the recipient, and an allowance of up to $1,000 for travel to attend a meeting of the Division of Particles and Fields (DPF) or APS, where the Award will be presented. The citation of the award certificate reads "For his unique contributions to current and future investigations of the newly discovered 125 GeV Higgs boson."

Dr. Vega-Morales did his Ph.D. under the supervision of Professor Ian Low and is now a postdoctoral Fellow at Laboratorie de Physique Theorique d'Orsay, Universit'e Paris-Sud in Paris, France."

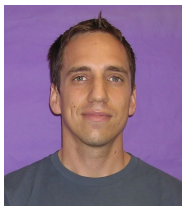
2013-2014 PhD Graduates



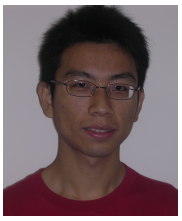
Sean Cornelius (Adilson Motter). Thesis title: Cascades, Control, and Compensatory Perturbations in Complex Networks.

William Gannon (William Halperin). Thesis title: Neutron Scattering Experiments with the Unconventional Superconductor UPt3.

Sanghamitra Goswami (Frederic Rasio). Thesis title: Formation and Evolution of Black holes in Dense Massive Clusters.



Andy Kubik (Michael Schmitt). Thesis title: Measurement of the Differential Final State Radiation Photon Cross section in Drell-Yan Di-Muon Events at CMS".



Cheuk Yui Leung (Michael Bedzyk). Thesis title: Electrostatically Driven Assenbly of Charged Amphiphiles Forming Crystallized Membranes, Vesicles and Nanofiber Arrays.

Andrew Mounce (William Halperin). Thesis title: Nuclear magnetic resonance study of high temperature superconductivity.

Sangwon Oh (William Halperin). Thesis title: Nuclear Magnetic Resonance study on the pnictide superconductors in high magnetic fields.

Vaishnavi Rajagopal (Brian Odom). Thesis title: Trapped Ion Thermometry and Mass Determination Through Imaging.

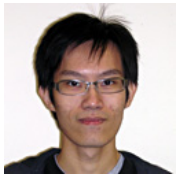
Emmanouela Rantsiou (Frederic Rasio). Thesis title: Mergers of Black Hole--Neutron Star Binaries: Gravitational Waves and the short GRB connection.

Shashank Shalgar (Andre de Gouvea). Thesis title: Transition magnetic moment and collective neutrino oscillations.

Thomas Sisan (Seth Lichter). Thesis title: Single-file transport through carbon nanotubes.

David Tabor (Brian Odom). Thesis title: Rovibrational Cooling of SiO+.

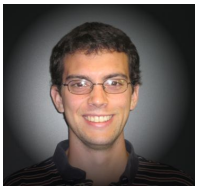
Roberto Vega-Morales (Ian Low). Thesis title: Scrutinizing the Higgs Couplings to Gauge Bosons.



Tsing Wai Wong (Vicky Kalogera). Thesis title: Compact Object Forensics---The Question of Origin.

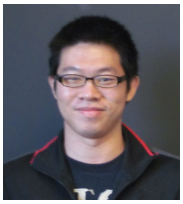
Nastaran Hadizadeh Yazdi (John Marko). Structure and Dynamics of the Bacterial Chromosome in E. coli.

2013-2014 Masters of Science Graduates



Peter Ashton (Giles Novak).
He is continuing with PhD studies in Physics and Astronomy at NU.

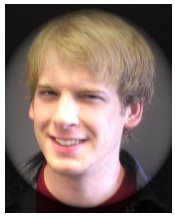
Jeffrey Berryman (Andre de Gouvea)
He is continuing with PhD studies in Physics and Astronomy at NU.



Yen Jung Chen (Nate Stern).
He is continuing with PhD studies in Physics and Astronomy at NU.

Fani Dosopoulou (Vicky Kalogera).
She is continuing with PhD studies in Physics and Astronomy at NU.

Young Pyo Hong (Jim Sauls).
He is continuing with PhD studies in Physics and Astronomy at NU.



Erik Lenferink (Anupam Garg).
He is continuing with PhD studies in Physics and Astronomy at NU.

Icon Mazzaccari (Anupam Garg) graduated Fall 2013.

Matthew Rickert (Farhad Zadeh).
He is continuing with PhD studies in Physics and Astronomy at NU.

Marc Royster (Farhad Zadeh).
He is continuing with PhD studies in Physics and Astronomy at NU.

Joel Schwartz (John Marko).
He is continuing with PhD studies in Physics and Astronomy at NU.

Niharika Sravan (Claude-Andre Faucher-Giguere).
She is continuing with PhD studies in Physics and Astronomy at NU.

Han Yan graduated Summer 2013.

2014 Senior Class Graduates

We want to congratulate all of our graduates and wishing you all the best:

Gregory Anthony will pursue a PhD in Medical Physics at the University of Chicago.

Ben Godek will pursue a PhD in Physics at the University of Virginia.

Hillary Hass is going to work on her own start-up.

Jonathan Kernes will pursue a PhD in Physics at UCLA.

Tyler Rehak will be assisting Professor Art Schmidt in the undergraduate labs.

Ingrid Ringler is going to study graphene supercapacitors in Munich, Germany over the summer, and in the fall will study nanotechnology at SUNY Albany. Also, Ingrid will practice capoeira again.

Daniil Abramov

Tyler Cowdrey

Caroline Darin

Daniel Goodman

Adriana Guzman

William Lassman

John Thao Le

Matthew Morrow

Michael Psitos

Kashyap Saxena

Daniel Thomas

Undergraduate Achievements

Nicholas M. Boffi, Physics senior has received a DoE Computational Science Graduate Fellowship. Nicholas will attend graduate school at the University of Chicago, starting in Fall 2015. First he will spend a year in Israel as part of the Fulbright U.S. Student Program.

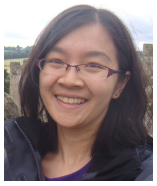
James Bueghly has been awarded a grant by Northwestern's Undergraduate Research Grant Program to work with Professor Mayda Velasco this summer. His project is titled Measuring Higgs Boson H c c Coupling.

Scotty Coughlin was awarded first prize in the Undergraduate-Student category for his poster "Parameter Estimation of Numerical Relativity Binary Black Hole Gravitational Waves in Early aLIGO noise", which he displayed at Northwestern's Computational Research Day. Now a senior, Scotty has worked with Professor Kalogera's LIGO (Laser Interferometer Gravitational-wave Observatory) group since the summer of his freshmen year. His poster was written in collaboration with Conner Skeehan, Mike Coughlin, Ben Farr, and Professor Vicky Kalogera.

Scotty has been using Northwestern's high-performance computer, "Quest", to better understand how to use gravity waves to constrain properties of black holes.

The Weinberg College of Arts & Sciences Awards for Physics and Astronomy Undergraduate Students:

Rui Chen was awarded Best Sophomore in Physics and Astronomy.



Xiaowen Chen was awarded Best Junior in Physics and Astronomy. Also, she received the Katherine L. Krieghbaum Scholarship Award as well as a Weinberg Summer Grant to work on a projext on doubly transient chaos with Professor Motter. She received the prize for Outstanding Achievement in Mathematics by a Junior too.

Erik Johnson was awarded the NU Summer 2014 Undergraduate Research Grant, his grant is titled "Negative Compressibility & Fibrin" and he is being sponsored by Professor Motter.

Jonathan Matthew Kernes was awarded Departamental Honors and Best Senior Thesis, his thesis title "Calculation of Feynman Diagram Topologies via Differential Equations of Pure integrals".

Graduate Achievements

Ben Farr, who works in Professor Vicky Kalogera's group, has been awarded the Robert R. McCormick Fellowship at the University of Chicago. He will start his work there on July 1st, focusing on gravitational-wave astronomy, and in particular, on the detection and characterization of compact binary mergers from their gravitational-wave and electromagnetic signatures.

Mark Kokish, first-year Chemistry graduate student, co-supervised by Brian Odom and Tamar Seideman, received a Graduate Research Fellowship from the National Science Fellowship, which provides full tuition and stipend support for three years, is highly prestigious; NSF received over 14,000 applications for the 2014 competition, and made 2,000 fellowship offers. Kokish was awarded the fellowship for his proposal to demonstrate experimentally the use of near-resonant light to monitor the orientation of trapped molecules, down to the single-molecule level.

Meagan Morscher is managing with Michelle Paulsen, in OSEP, the new "Graduate Student Speaker Series". The Graduate Student Speaker Series (GS3) is a newly-launched program that has been created as an extension of two CIERA programs: Reach for the Stars (managed in collaboration with the Office of STEM Education Partnerships, or OSEP) and Ready, Set, Go (in collaboration with Northwestern's Graduate School). In this program, Northwestern Ph.D. candidates visit local high schools to present their cutting-edge research to small groups of STEM teachers, answer questions, and discuss ways to incorporate the research content into the high-school classroom. GS3 hosted a kick-off event at Maine East High School on February 6th. All high school STEM teachers were encouraged to join to learn about the exciting research being done at Northwestern across many STEM disciplines.

Resham Sarkar received the Student Award for Engagement from the Dean of The Graduate School. This award recognizes the phenomenal work she has done on behalf of the Graduate School. She works with Professor Selim Shahriar.

Niharika Sravan was awarded first prize in the Graduate Student category for her poster "Watching Galaxies Grow Up! Observations of the Circum-Galactic Medium", which she presented at Northwestern University's Computational Research Day on April 22nd. Niharika is a third-year graduate student who is working with Dr. Claude-André Faucher-Giguère (currently an Einstein Fellow, at CIERA) on numerical simulations of galaxy formation. Niharika's work focuses on analyzing simulations of forming galaxies; her work will help astronomers interpret observations of gas around galaxies and thereby help us understand how much material galaxies eject in the course of forming black holes and stars.

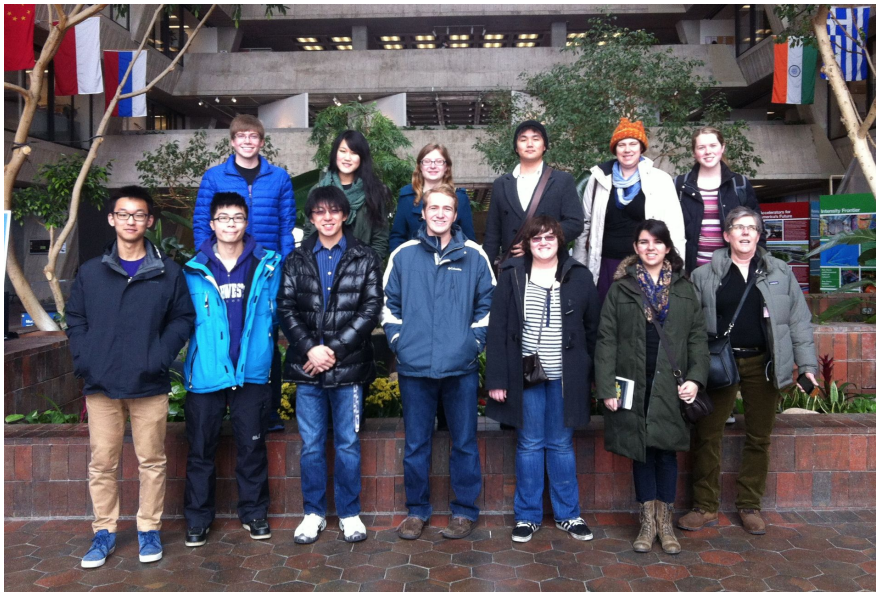
Thomas Wytock has received the Society for Industrial and Applied Mathematics-SIAM Student Chapter Certificate of Recognition.Thomas was one of the founding members of the NU SIAM Student Chapter in November 2011 and has served as president of the Chapter for the past two and a half years. He works with Professor Adilson Motter.

Staff News

Leah Handel has been promoted to Graduate Secretary. Her new responsibilities include supporting the Director of Graduate Studies and the Graduate Admissions committee and serving as the departmental point of contact for graduate students.

Northwestern's Society of Physics Students (SPS)

SPS took a trip to Fermilab National Accelerator Laboratory and were shown around by Northwestern Professor Heidi Schellman.



In winter quarter 2014, the Society of Physics (SPS) students visited Fermilab National Accelerator Laboratory. Professor Heidi Schellman and graduate student Cheryl Patrick led the students on a tour of the facility, exploring the main administration building, the underground accelerator, and other areas of the facility. The group learned a lot about the research being done at Fermilab with the particle accelerators. This spring quarter, the Society of Physics students hosted its annual physics major dinner at Prairie Moon. The professors and physics majors had fun talking, enjoying the food, and spending time together outside of class. SPS is excited to announce that it has achieved B status recognition from the Associated Student Government and will now receive ASG funding towards next year's events!

SPS has also elected its executive board for the 2014-2015 school year.

The members of the executive board are:

Kelly Powderly, President

CJ Hansen, Vice President

Daniela DeLeon, Secretary

Insu Paek, Programming Chair

Alek Jansen, Marketing Chair

Lauren Barmore, Photography Chair

The new exec board is very excited about planning events for the coming quarters!

Physics students and professors sat down for a meal together at the annual Physics Majors Dinner at Prairie Moon.

Department Events

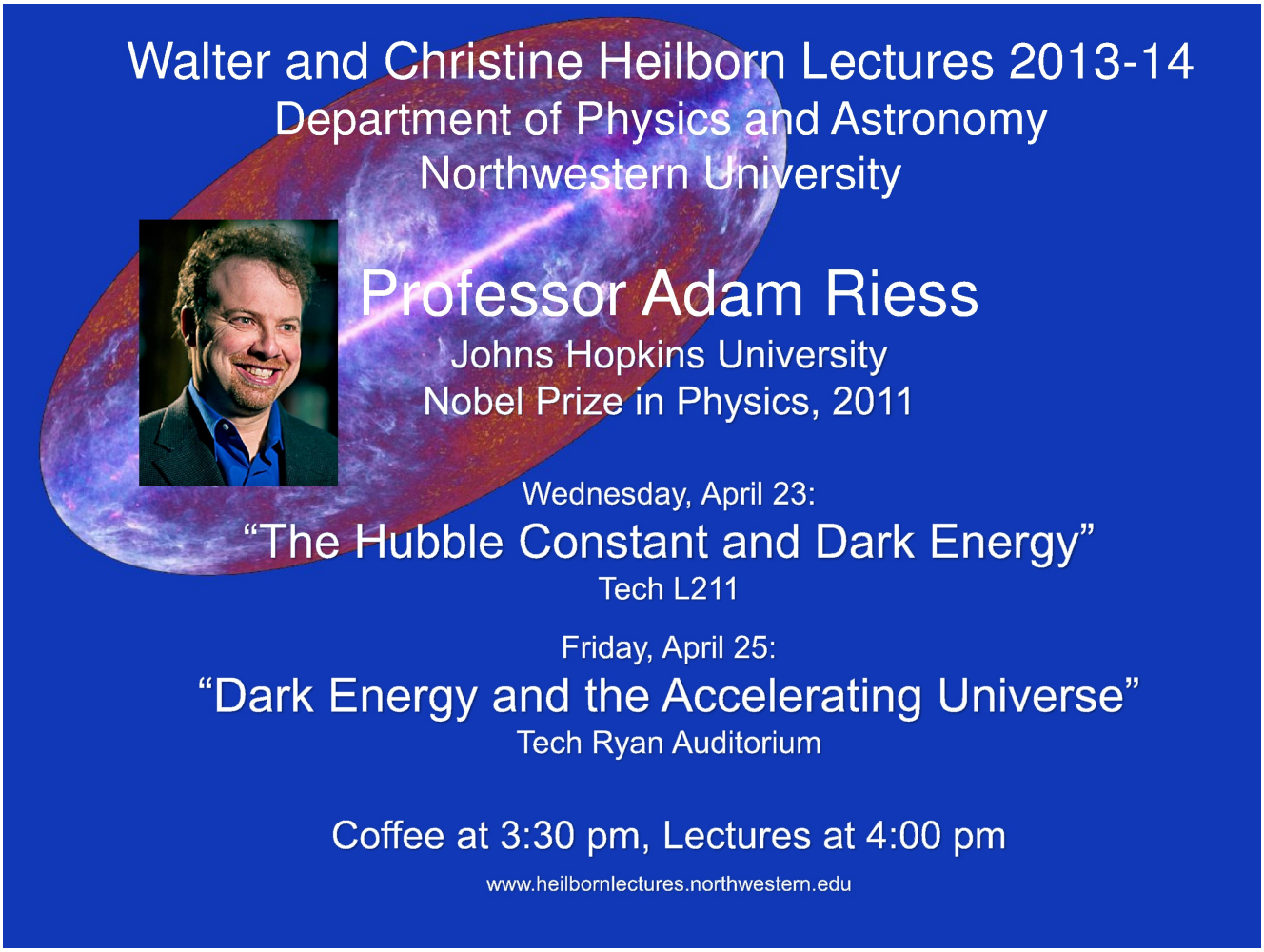
CIERA Celebrates its Move to the Tech Institute with Ribbon Cutting & Open House

On Wednesday, March 5th, CIERA celebrated its new facility with a Ribbon Cutting Ceremony and Open House. Over 70 people from across Northwestern University attended the Open House, including Provost Linzer, Vice President of Research Walsh, Weinberg College of Arts and Sciences Dean Mangelsdorf, McCormick Dean Ottino, Associate Vice President for Research Cao, and Department of Physics and Astronomy Chair Schellman. The program started with brief remarks by Provost Linzer, who cut the ceremonial ribbon; this was followed by a champagne toast led by Director Kalogera. CIERA's Director thanked the variety of people who made the beautiful new office space possible, from its inception to construction: a process that took approximately four years. The Open House ended with two tours through the new facilities, led by Professor Kalogera.

This new space is extremely important to CIERA, as the astrophysics group at Northwestern has been growing rapidly, bringing in top postdoctoral fellows & graduate students to Northwestern, drawing in visitors from across the country, and pioneering innovative research and education programs on campus and throughout Chicago. CIERA's astronomy core was originally housed in Dearborn Observatory; the Observatory had been a natural home, for many years, for astronomers studying black holes, the atmospheres of planets that circle other stars, binary star systems, the Galaxy, clusters of thousands of stars, and clusters of galaxies. But, according to CIERA Director and Erastus O. Haven Professor of Physics & Astronomy Vicky Kalogera, "as much as we loved the charm, quirkiness, and warmth of Dearborn Observatory, the last couple of years the Observatory was bursting at the seams as CIERA attracted prize postdoctoral fellows and expanded our astronomy research and STEM [Science, Technology, Engineering, and Math] education projects."

After years of preparation, newly-renovated office space was created for CIERA on the 2nd-floor of the F Wing of the Technological Institute; the move into the new space was completed in October, 2013. As beautiful as the new offices are, they represent more than just a renovated space. As explained by Professor Kalogera, "equally important is the cohesiveness and interaction that the new space fosters: almost everyone in the astronomy group is now on one floor. Impromptu meetings, gatherings and discussions of new projects happen daily, and even more significant, we are a few steps away from our interdisciplinary collaborators in Physics, Earth & Planetary Sciences, and also very close to Applied Math, Computer Science, and Mechanical & Electrical Engineering. The proximity and availability of interaction spaces is already affecting how we discuss things, brainstorm, and work together when opportunities arise." With CIERA's new offices, meeting rooms, and more accessible location, the astronomy group is even better placed, now, to achieve its goal of a nationally-recognized center of astrophysics research with strong, unique interdisciplinary ties.

Heilborn Lectures 2014:



The Department of Physics & Astronomy has been organizing a highly successful annual series of Heilborn Lectures since 2001. The series was endowed by our alumnus George Heilborn in honor of his parents, George and Christine Heilborn, and has hosted eight Nobel Prize winners in previous years. For 2013-14 the distinguished lecturer was Professor Adam Riess of Johns Hopkins University, recipient of the 2011 Nobel Prize for the discover that the Universe is expanding at an increasing rate.

In addition to his distinguished research and teaching at Johns Hopkins, Professor Riess has received numerous prizes and awards, including a MacArthur prize, Einstein Medal, Shaw Prize, Gruber Prize, Townes Prize, and others. He is a member of the National Academy of Sciences.

During his stay from April 23-25, he delivered two lectures, "The Hubble Constant and Dark Energy" and "Dark Energy and the Accelerating Universe." The latter was a public lecture attended by over 500 people from the University and general public. The event was capped by a banquet in honor of Prof. Riess at the Chef's Station Restaurant. It was enjoyed by faculty, administration, George Heilborn, and guests.

Physics Outreach at the AAAS Family Science Days

In February 2014 - Members of our department showcased a variety of Physics demonstrations over the weekend at the Family Science Days hosted in downtown Chicago by the AAAS. These demonstrations were, in part, sponsored by Professor Jens Koch's NSF CAREER grant.

2014 Chicago Area SIAM Student Chapter Conference

The 2014 iteration of the Chicago Area Society for Industrial and Applied Mathematics- SIAM Student Chapters was a success thanks to the hard work of the organizing committee of Andrew Stine, Connor Schlick, Paul Park, Yang Yang and Thomas Wytock. Over fifty students participated with eleven giving talks. Dr. Stefan Wild, Prof. Hemanshu Kaul, and Dr. Christopher Henry delivered engaging invited talks. Students from institutions across the midwest, including Wisconsin, Notre Dame, and Loyola, participated making this a truly regional event.

Few student conferences cover the breadth of topics that CASSC 2014 did. Talks detailed research on machine learning, traffic design, computational biology, public health, and even education in the Chicago area. Every speaker did a wonderful job of motivating his or her research and engaging with the audience. Participants left with an appreciation for diverse fields and an awareness of new problems and methods. Hopefully, CASSC continues to be a forum for cross-pollination of ideas between different fields, priming the way for future innovation.

We would like to thank the generous sponsorship of the Northwestern Department of Physics and Astronomy and the support of Professor Adilson E. Motter – faculty advisor of the Northwestern Student Chapter of SIAM.

Dearborn Observatory Lunar Eclipse Viewing

During the pre-dawn hours of April 15, 2014, Evanston had its first chance to view a total lunar eclipse since December 2010. Despite inclement weather, the Dearborn Observatory was open to the public to view this event from 1-4 am CDT. Admission was free and all were welcome. Around 175 people attended the event and skys cleared enough at 3am for visitors to view the eclipse. Thank you to Annas Rahman, Sara Rastegar and Sam Cohen, who worked the event.

Photo courtesy of Annas Rahman

Winter 2014 CIERA Interdisciplinary Colloquium:

CIERA was happy to host Tony Tyson, Chief Scientist of the Large Synoptic Survey Telescope (LSST), for the Winter Interdisciplinary Colloquium on Monday February 17th. In the Fall Interdisciplinary Colloquium, LSST Data Scientist Dr. Mario Juric had addressed the overall structure of LSST and the challenges of analyzing the torrent of data from the telescope; in this talk, Dr. Tyson focused on the telescope optics, its instruments, and the ability of the LSST to test questions relating to the structure of the Universe: observations that would help constrain both Dark Matter and Dark Energy. His talk was attended by an audience of about 50 interdisciplinary researchers; Dr. Tyson also met personally with 16 members of CIERA, including graduate students, postdocs, and faculty.

2014 CIERA Public Lecture:

Photo courtesy of Bethany Hubbard

Dr. Maria Zuber, Griswold Professor of Geophysics and Vice President for Research at MIT, gave CIERA's Fifth Public Lecture on Thursday, April 3rd. She introduced the audience to the "New Moon" that has been revealed by detailed maps of the Moon's structure made by a pair of lunar satellites called GRAIL (Gravity Recovery and Interior Laboratory). These new maps have helped inform new models of how the moon as formed, and how the inner solar system evolved very early in the history of our Sun's worlds. Professor Zuber also spent the day at Northwestern, speaking with administrators, faculty, and students.

CIERA Sponsors Poster Session at Northwestern's Computational Research Day

On Tuesday, April 22nd, computational researchers from across Northwestern met for Computational Research Day: a series of talks, panel discussions, and a poster session, which all focused on the way that high-performance computing helps researchers on both the Evanston and downtown campuses. The event was hosted by Northwestern University's IT group, and sponsored by the McCormick School of Engineering, the Weinberg College of Arts and Sciences, CIERA, Northwestern's Library, and the Office for Research. CIERA supported and helped to organize the interdisciplinary poster session, which brought together 20 researchers from the Departments of Chemistry, Chemical & Biological Engineering, Electrical Engineering and Computer Science, Materials Science, Biomedical Engineering, Mechanical Engineering, Neurology, Physics & Astronomy, as well as Northwestern's Brain Tumor Institute, the Rehabilitation Institute of Chicago, and the Research Center of the Ann & Robert H. Lurie Children's Hospital of Chicago. As part of the poster session, the posters were judged by seven volunteers, and five awards were given:

Postdoctoral Research Poster Awards:
First Prize:
Diego Gomez-Gualdron
(Department of Chemical and Biological Engineering)
Second Prize (Tie):
David Malaspina
(Department of Biomedical Engineering)
Joshua Jacobs
(Northwestern's Brain Tumor Institute)

Graduate Student Poster Awards:
First Prize:
Niharika Sravan
(Department of Physics and Astronomy)
Second Prize:
Alireza Bonakdar
(Department of Electrical Engineering
and Computer Science)

Undergraduate Student Poster Award:
First Prize:
Scott Coughlin
(Department of Physics and Astronomy)

Many thanks to our judges, for their work! Elizabeth Hicks, John Everett, Alex Hryn, Lindsey Madison, John Gibbs, Pavan Ramkumar, and Daniel Wood reviewed the posters and talked with the participants over the course of the main, one-hour poster session.

Dimensions was compiled by Monica Brown

Please visit the Physics and Astronomy website for a complete list of upcoming events:
www.physics.northwestern.edu/events
Be sure to check out our Facebook Fan page and our LinkedIn Group Page.
Type in "Department of Physics and Astronomy, Northwestern University".

Alumni News

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Degree: _____

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e-mail Address: _____

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The department newsletter is a means of reaching out to the alumni to keep them abreast of current research and developments in the Department of Physics and Astronomy. It is also a forum for alumni to keep the department informed of their accomplishments; the department welcomes submissions from alumni of newsworthy items for publication in the newsletter. Please feel free to send in items using this form (just fold and staple the page), or to email your news to Monica Brown monica.brown@northwestern.edu.

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