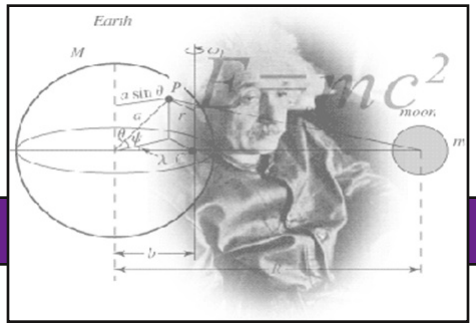
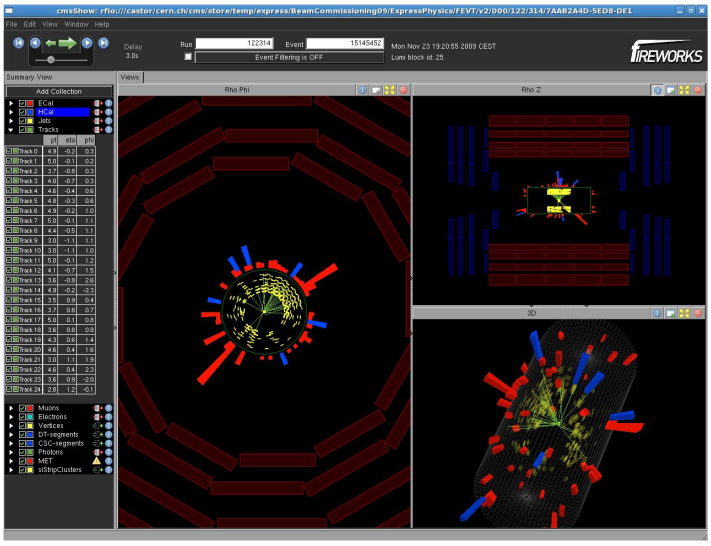
Dimensions

Department of Physics and Astronomy



The CERN Large Hadron Collider Is On!

Members of the Northwestern CMS Team pose in front of the CMS End Cap detector, during the commissioning period of 2009. The CMS Detector recorded the first LHC collision data on Nov 23, 2009. From left to right: **Steve Won** (grad student working with Prof. Velasco), **Andy Kubik** (grad student working with Prof. Schmitt), **Radek Ofierzynski** (post-doc working with Prof. Velasco), **Prof. Mayda Velasco**



CMS first candidate 900GeV collisions, Monday, 11/23/2009
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IN THIS ISSUE

Please visit the Physics and Astronomy website for a complete list of upcoming seminars: www.physics.northwestern.edu/events/

Letter from the Chair

Dear Friends of Physics and Astronomy,

Our Department looks forward to much excitement in the year 2010. I am pleased to announce the addition of a new faculty member in computational theoretical astrophysics: Yoram Lithwick will be joining the faculty as an Assistant Professor in January. He comes from the Canadian Institute for Theoretical Astrophysics, where he is currently a Senior Research Associate. We also have two ongoing searches for faculty members, one in the theory of quantum state manipulation, and one, joint with Argonne National Laboratory, in high energy theory.

We look forward to two events taking place in January: Dynamics Days 2010 (http://ddays2010.northwestern.edu) and the Heilborn Symposium (http://www.heilbornsymposium.northwestern.edu). Celebrated speakers for these events include James Yorke of the University of Maryland, Michael Syphers of the Fermi National Accelerator Laboratory, Jacques Laskar of the Paris Observatory, and Nobel Prize winner Murray Gell-Mann of the Santa Fe Institute and Cal Tech, as well as Yoram Lithwick and Jim Sauls from our own department.

We also eagerly anticipate the February university-wide inauguration of the Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA), a new endowed Northwestern University Research Center, directed by our faculty members Fred Rasio, Dave Meyer, and Vicky Kalogera. Participants include faculty from Physics and Astronomy, Earth and Planetary Sciences, Electrical Engineering and Computer Science and Engineering Sciences and Applied Mathematics. CIERA's mission is to promote interdisciplinary research and education related to astrophysics.

This has been a year of tremendous change in Physics and Astronomy. The change with the most obvious impact has been the beginning of the construction of the University's new state-of-the-art clean room. This new facility is being built in what is called the FG infill, that is, the area on the south side of the Tech Institute building between the F and G wings. Some of you may recall that part of this area housed the "Annex," where the offices for first year graduate students were usually located. It also encompasses the (now former) High Energy Physics High-Bay area. The annex is now demolished, and construction of the foundations of the building is scheduled to commence in a few months. The project should take a total of 18 to 24 months to complete. One impact of the infill project is that many offices were reallocated in Fall 2009, in order to accommodate the loss of windows along the south side of F-wing.

The quality of our undergraduate program continues to improve. The number of undergraduate physics majors is currently 53, and a great number of them are actively involved in research, seven of them having completed honors theses for graduation. They have won numerous prestigious external awards, including the Churchill Scholarship and the Goldwater Scholarship, and a large fraction of them continue on to graduate studies at top universities.

This year, we also had a larger number of students admitted to our graduate program, in part due to a new $3M NSF-funded Integrative Graduate Education, Research and Training (IGERT) grant for Quantum Coherent Optical and Matter Systems. This grant is a collaborative effort between the Departments of Chemistry, Electrical and Computer Engineering, Materials Science and Engineering, and Physics and Astronomy.

Several of our graduate students were the recipients of fellowships this year. Laszlo Frazer was awarded The Ryan Fellowship from The Graduate School. Nick Hatcher received the NASA Graduate Student Researchers Program Fellowship. Tristan Matthews and Meghan Morscher both won a $10,000 Illinois Space Grant Fellowship, from the NASA Illinois Space Grant Consortium. Well done!

Finally, congratulations go out to several faculty who have received awards and promotions. Vicky Kalogera has been appointed the Erastus O. Haven Professor of Physics and Astronomy, and was also made a Fellow of the American Physical Society. Brian Odom received a CAREER award, a Packard Fellowship in Science and Engineering and an Air Force Office of Scientific Research Young Investigator Award. Fred Rasio has been appointed the Joseph Cummings Professor of Physics. Finally, Michael Smutko was elected a third time to the Associated Student Government's Faculty Honor Roll.

With best wishes,

Venkat Chandrasekhar, Professor and Chair
Department of Physics & Astronomy

Trapped Molecules as Probes of Fundamental Physics

by Brian Odom

The development of laser cooling and trapping, for which the 1997 Nobel prize was awarded, led to a revolution in the field of Atomic, Molecular, and Optical (AMO) physics. Atoms illuminated by intense laser beams of the right color are slowed down (laser cooling), rather than heated as one might expect. Cooled atoms can then be held, further cooled, and studied in the gentlest imaginable of containers, where the "walls" are made of electric or magnetic fields (trapping). One of the crowning achievements of this revolution was the creation of Bose-Einstein condensates, a new phase of matter where large numbers of atoms crowd into the same quantum state—work for which the 2001 Nobel prize was awarded.

Before the advent of laser cooling, there was no reason to favor working with atoms over molecules, and in fact most AMO research was performed on molecules. However, the laser cooling and trapping revolution turned the tables—atoms could be cooled to temperatures *billions* of times lower than molecules, and measurement of atomic energy levels (spectroscopy) could be performed *thousands* of times better than for molecules. With their endless variety and rich internal rotational and vibrational structure (completely lacking in atoms), molecules have always been recognized as holding great promise. However, precisely because of their rich internal structure, molecules have proven much more difficult to cool and study. Over the last decade, several new techniques have been developed to cool and control molecules, making it possible for molecular complexity to be converted from a weakness into a strength. Many physicists think that the next revolution in AMO has begun—with molecules once again coming into the fore.

About the Author

Brian Odom is a Professor of Physics at Northwestern University. He attended Stanford University for his undergraduate studies in Physics, and received his PhD in Physics from Harvard University in 2004. He went on to work for the Kavli Institute at the University of Chicago as a Cosmological Physics Postdoctoral Fellow from 2004-2008. Brian joined the faculty of the Department of Physics and Astronomy at Northwestern University in 2008. His research is focused on manipulation and study of sub-Kelvin trapped molecular ions.

In my laboratory at Northwestern, we work with trapped molecular ions (molecules missing one or more electrons), cooling them a fraction of a degree above absolute zero without the use of any cryogenic liquids. Our cooling technique, pioneered over the last decade by two European groups, uses laser-cooled *atomic* ions to sympathetically cool the *molecular* ions. One of the first innovations we plan to develop at Northwestern is molecular quantum logic spectroscopy (mQLS), in which a *logic ion* (a laser-coolable atom) serves the dual role of cooling to milliKelvin temperatures and reading out the internal state of a *spectroscopy ion* (a non-laser-coolable molecule).

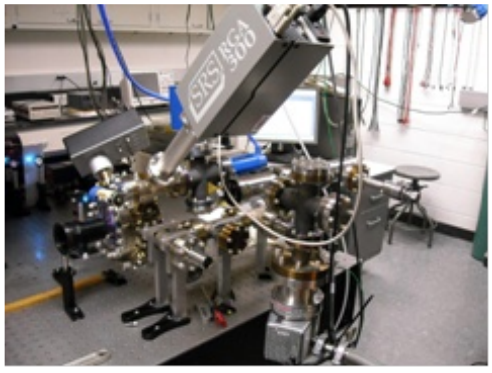


Fig. 1: (a) Vacuum chamber housing our first trap for molecular ions.

Fig. 1: (b) Assembly of the entire laboratory apparatus.

The quantum logic spectroscopy technique has recently been applied to atoms, but its molecular counterpart remains a goal in the field. Two breakthrough outcomes will result from the development of mQLS: (1) the first high-accuracy spectroscopy on *isolated* single molecules (compared to existing single-molecule techniques where energy levels are perturbed by

the environment); and (2) molecular spectroscopy with accuracy surpassing that of conventional methods by three orders of magnitude. What good is better molecular spectroscopy? We have two applications in mind: making the first observation of a fundamental symmetry-violating difference between left- and right-handed molecules and searching for time-variation of fundamental constants.

I. Mirror-Symmetry Breaking at the Molecular Level

Nature is very nearly mirror-symmetric; interactions involving the three most important forces—*gravity*, *electromagnetism*, and the *strong nuclear force*—appear to follow the normal laws of physics even when viewed through a mirror. When we consider molecular structure, if nature were adequately described by those three forces, we would expect left-handed and right-handed versions of chiral (i.e. twisty) molecules to be identical in all their properties, such as their resonant stretching frequencies. However, the least influential force—the *weak nuclear force*—breaks mirror symmetry and leads to a surprising prediction: right-handed molecules should vibrate at frequencies slightly different from their left-handed counterparts (up to 1 part in 10^{12} for certain molecules—**Fig. 2**).

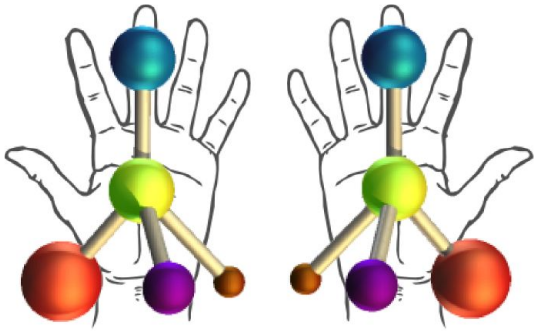


Fig. 2: (a) Chiral mirror-image molecules.

To date, conventional spectroscopy has failed to find a fundamental left/right asymmetry in chiral molecules, because the achieved accuracy falls short by several orders of magnitude. In contrast, mQLS on *individual molecules* will improve our capability to measure molecular energy levels by orders of magnitude, bringing well within reach the required accuracy. Observation of a fundamental left/right molecular asymmetry by mQLS would represent the first demonstration of mirror-symmetry violation in the intrinsic structure of stable matter, and precision measurements of this effect would constitute a search for yet-unknown physics.

II. Time-variation of Fundamental "Constants"

Most of the time, we assume that constants are well-named, in that their values do not vary in time. However, time-variation of constants is actually predicted by many theories attempting to reconcile quantum mechanics with gravity. Some controversial astronomical observations have suggested a time-variation of constants (e.g. 1 part in 10^{15}/year for the electron-to-proton mass ratio μ) on *cosmic timescales*. Looking over *one year* for time-varying spectra with a carefully designed apparatus, however, can address these questions with higher confidence by better controlling sources of error.

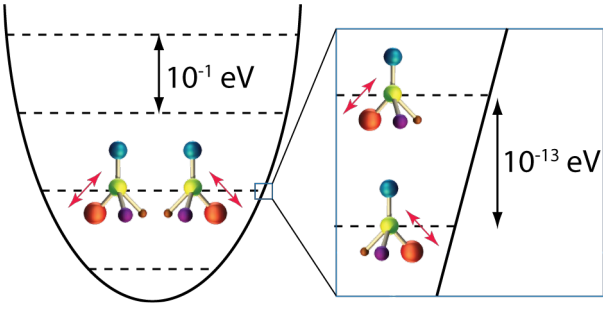
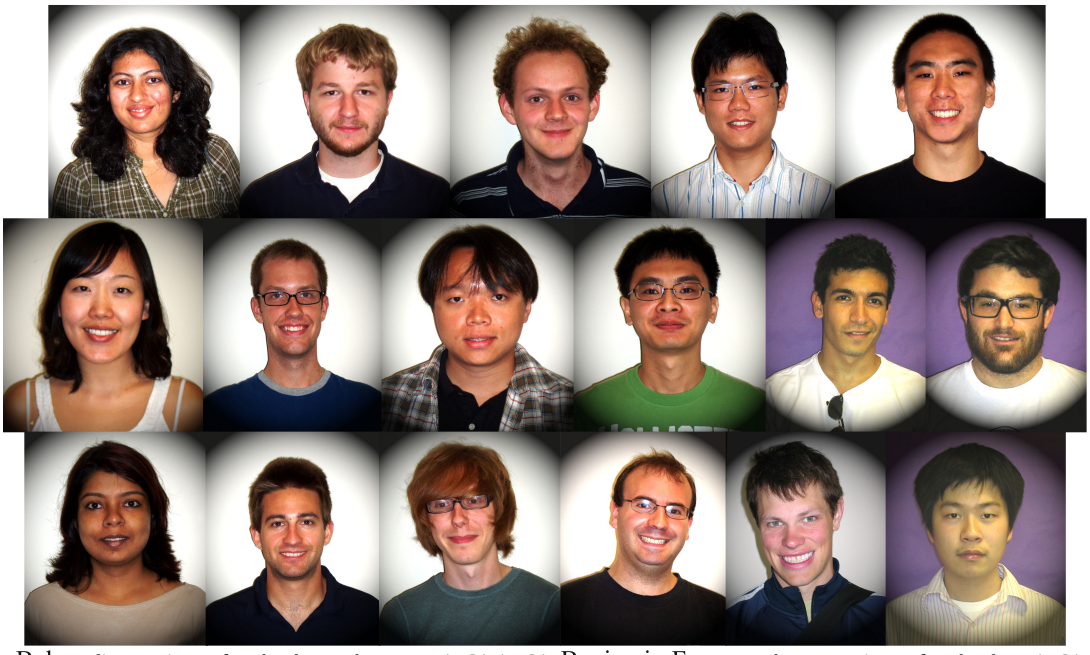


Fig. 2: (b) Scheme of the predicted vibrational energy level differences between left- and right-handed molecules.

Since molecular vibrations depend on the proton mass, they are sensitive to time-varying μ. Using mQLS on a suitable molecule to continuously monitor specially selected molecular vibrations, we expect to measure $\Delta\mu$ to 1 part in 10^{17}/year—two orders of magnitude *better* than the astrophysical sensitivity. A discovery that μ does indeed change with time would likely play a crucial role in unification of quantum mechanics with gravity and the development of a single "theory of everything".

Welcome to our Incoming Graduate Students!



Row 1: Varada Bal - *Indian Institute of Technology, Kharagpur (B.S.) (M.S.),* Benjamin Farr - *Rochester Institute of Technology (B.S.),* Laszlo Frazer - *University of Chicago (B.A.),* Ting-Chung Huang - *National Taiwan University (B.S.),* Jason Hwang - *Pennsylvania State University (B.S.)*

Row 2: May Kim - *Wellesley College (B.A.) Michigan Technological University (M.S.),* Andrew Kobach - *University of Notre Dame (B.S.),* Chien-Yu Lien - *National Tsing Hua University (B.S.) (M.S.),* Yen-Wei Lin - *National Tsing Hua University (B.S.),* Brian Pollack - *Carnegie Mellon University (B.S.),* Marc Royster - *University of California, Santa Barbara (B.S.)*

Row 3: Resham Sarkar - *Indian Institute of Technology, Kharagpur (B.S.) (M.S.),* Christopher Seck - *California Polytechnic State University (B.S.),* Joseph Sklenar - *Case Western Reserve University (B.S.),* Jonathan Trossman - *University of Illinois at Urbana-Champaign (B.S.),* Thomas Wytock - *Northwestern University (B.A.),* Guanyu Zhu - *Shanghai Jiao Tong University (B.S.)*

CTEQ Workshop

Northwestern University hosted the 2009 CTEQ (Coordinated Theoretical-Experimental Project on QCD) workshop on November 20 & 21. The workshop was organized by Prof. Heidi Schellman.

QFS2009: International Symposium on Quantum Fluids

Northwestern University hosted the QFS2009: International Symposium on Quantum Fluids and Solids on August 5 - 11. This conference continued a long standing tradition of such conferences from 1975, conferences held two out of every three years, skipping the year of the International Low Temperature Conference where the subjects traditionally developed in quantum fluids, solids, and gases are well represented. The conference was attended by 250 people from 28 countries including 4 Nobel Laureates. This conference was organized by Prof. Bill Halperin and Prof. Jim Sauls.

Northwestern University has announced a new endowed University Research Center in astrophysics named CIERA: Center for Interdisciplinary Exploration and Research in Astrophysics.

CIERA's mission is to promote research and education through the support of postdoctoral fellows developing independent research programs, advanced graduate and undergraduate research, seminar series, a long-term visitors program, and seed funding for pursuing new astrophysics research directions. Special emphasis is given to interdisciplinary connections with planetary science, computer science, applied math, statistics, chemistry, biology, electrical engineering, and materials science.

CIERA was officially established on September 1, 2009. Fred Rasio, Dave Meyer, and Vicky Kalogera serve as inaugural co-directors. Faculty from Physics and Astronomy, Earth and Planetary Sciences, Electrical Engineering and Computer Science, Engineering Sciences and Applied Mathematics, and other departments joined as CIERA members, and were also invited to serve on its Advisory Board.

The university-wide inaugural events, including a colloquium by Geoff Marcy (UC Berkeley) will take place on February 5, 2010.

We look forward to this new activity, as the establishment of CIERA will greatly contribute to the advancement of research and education in our department and broadly at Northwestern University.

Student and Postdoc News

Laszlo Frazer, working with John Ketterson, was awarded The Ryan Fellowship from The Graduate School. The Ryan Fellowship, made possible by a generous donation from Patrick G. and Shirley W. Ryan, supports graduate students dedicated to the exploration of fundamental nanoscale science and to advancing this knowledge into practical applications of benefit to society.

Nick Hatcher, working with Art Freeman, has received the NASA Graduate Student Researchers Program (GSRP) Fellowship. The NASA GSRP awards fellowships for graduate study leading to master's or doctoral degrees, related to NASA research and development, in the fields of science, mathematics and engineering. This 12-month award includes an internship at a NASA center.

Tristan Matthews and **Meghan Morscher** both won a $10,000 Illinois Space Grant Fellowship, from the NASA Illinois Space Grant Consortium.

Zachary G. Nicolaou, who was selected Outstanding Junior in Physics and Astronomy earlier this year, has received the Krieghbaum Scholarship and the Outstanding Achievement in Mathematics by a Junior Award. Zack is a senior in physics, mathematics and ISP major working with Prof. Adilson E. Motter on a two-year research project funded by the MRSEC Undergraduate Research Program. Last spring, he was elected to the Phi Beta Kappa Honor Society.

Radek Ofierzynski won the CMS Research Achievement award for 2009 for his work done in the Hadronic Calorimeter. Ofierzynski is a research associate working with Prof. Velasco since 2007. Previously, he received his PhD at ETH Zurich on the L3-LEP experiment at CERN and was awarded a CERN fellowship after graduation.

Faculty News

Vicky Kalogera has been appointed the Erastus O. Haven Professor of Physics and Astronomy. Erastus Haven was the third President of Northwestern University from 1869 - 1872 and accepted the presidency on the condition that Northwestern admit women; he was also responsible for instituting a more progressive curriculum that expanded teaching from the traditional classics fields to include the sciences.

Brian Odom received a CAREER award, the National Science Foundation's most prestigious support for junior faculty who exemplify the role of teacher-scholars.

He was awarded a Packard Fellowship in Science and Engineering by the David and Lucile Packard Foundation. He is among the 16 science and engineering researchers nationwide named this year to receive the unrestricted research grant of $875,000 over five years. NU Newscenter article: www.northwestern.edu/newscenter/stories/2009/10/odom.html

Brian was also selected as an Air Force Office of Scientific Research Young Investigator!

Fred Rasio has been appointed the Joseph Cummings Professor of Physics. Joseph Cummings was the fifth president of Northwestern University from 1881-1890, who promoted the development of Physics and Astronomy on campus and oversaw the construction of Dearborn Observatory in 1888-89. The Dearborn telescope was then the largest refracting telescope in the world (until Yerkes Observatory was founded in 1897).

Art Schmidt and **Tom Senior** gave a presentation on sound and music to middle and high school students. The event was hosted at the Arlington Heights Memorial Library "Science Squad".

Michael Smutko was elected to the Associated Student Government's Faculty Honor Roll for the third time.

He appeared live on WTTW's "Chicago Tonight" with Phil Ponce to discuss the 40th anniversary of Apollo 11 and the future of the space program. The video can be found here: www.wttw.com/main.taf?p=42,8,8&vid=072009e

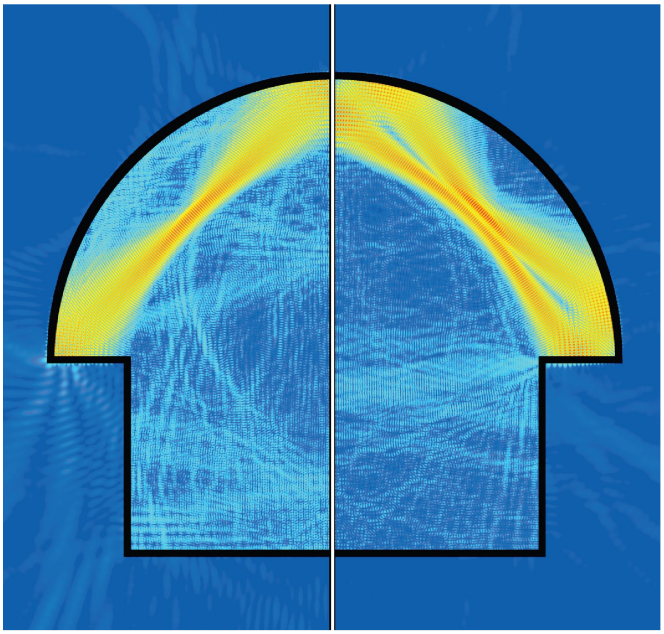
He was invited by the director of undergraduate admissions to speak at a symposium for Chicago Public School students. The event was written up in "Crosscurrents", WCAS' newsletter: www.wcas.northwestern.edu/alumni/crosscurrents/2009-spring-summer/articles/chicago-public-schools-northwestern.html

Finally, Mike hosted solar viewing sessions for 100 students from McKenzie Elementary school and Evanston Arts Camps.

Selected Publications:

Adilson E. Motter

"Marginally Unstable Periodic Orbits in Semiclassical Mushroom Billiards", J. Andreasen, H. Cao, J. Wiersig, and A.E. Motter, Phys. Rev. Lett. 103, 154101 (2009). This paper, featured on the cover of the October 9 issue of Physical Review Letters, provides a novel approach to generate directional emission in optical microcavities. Instead of making the cavities themselves directional, this study shows that an alternative based on allowing the light to escape the cavity only to subsequently re-enter can efficiently force it to be emitted towards specific directions.



Cover art illustrating the mushroom-shaped cavities studied by Motter and his collaborators.

Pulak Dutta

"Structural signal of a dynamic glass transition", Sudeshna Chattopadhyay, Ahmet Uysal, Benjamin Stripe, Guennadi Evmenenko, Steven Ehrlich, Evguenia A. Karapetrova and Pulak Dutta, Phys. Rev. Lett. 103, 175701 (2009). It is thought that the structure of a glass is the same as that of the liquid phase of the same material. We show that there is, in fact, a sudden change in the surface structure across the glass transition.

Welcome New Faculty!

Yoram Lithwick will be joining the faculty as an Assistant Professor in January 2010. He joins us from the Canadian Institute for Theoretical Astrophysics, where he is currently a Senior Research Associate. Dr. Lithwick is a theoretical computational astrophysicist who works primarily on planet formation, and will add to the growing strength in this area of our department.

Douglas Roberts will be joining the faculty as an Adjunct Associate Professor in January 2010. He will be joining us from the Adler Planetarium in Chicago. Dr. Roberts is currently the Senior Director of Digital Technologies, where he created a plan to administer digital technologies thoughout the Planetarium and created a Digital Technologies organizational unit, and integration of Space Visualization Laboratory and Information Technology departments at Adler.

Retirement Party for David Buchholz
September, 2009

The Department hosted a party to celebrate the career of Professor David Buchholz, his research on the physics of heavy quarks, and his contributions to the success of our department. Many faculty, postdocs, staff, and students (former and current) attended the party to express our appreciation of David. We wish him well as he enjoys his retirement with his family in Keeseville, New York.

Heilborn Symposium 2010: Complexity

Northwestern University
Department of Physics & Astronomy

Walter & Christine

Heilborn Symposium

January 6 - 8, 2010

Dr. Yoram Lithwick

Assistant Professor of Physics & Astronomy
Northwestern University

"Secular Instability: Organization of Planetary Systems and the Formation of Hot Jupiters"

Wednesday, Jan. 6

Dr. Michael Syphers

Assistant Accelerator Division Head
Fermi National Accelerator Laboratory

"Relativistic Chaos: Nonlinear Dynamics in Large Particle Accelerators"

Thursday, Jan. 7

Dr. James Sauls

Professor of Physics & Astronomy
Northwestern University

"Quantum Transport in a Random Fractal"

Friday, Jan. 8

Coffee at 10:30 am, Lectures at 11:00 am
F235, Technology Institute
2145 Sheridan Road, Evanston, IL

www.heilbornsymposium.northwestern.edu

co-sponsored by Northwestern University's WCAS, TGS, NICO, C²ST & Adler

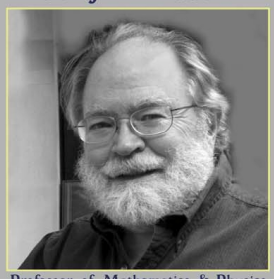
Northwestern University
Department of Physics & Astronomy

Walter & Christine

Heilborn Symposium

January 6 - 8, 2010

Dr. James Yorke



Professor of Mathematics & Physics
University of Maryland

"Chaos"

Wednesday, Jan. 6

Dr. Jacques Laskar

Director of Research CNRS
Paris Observatory

"Is the Solar System Stable?"

Thursday, Jan. 7

Dr. Murray Gell-Mann

1969 Nobel Prize Winner
Distinguished Fellow at Sante Fe Institute
Professor Emeritus at Caltech

"Simplicity and Complexity"

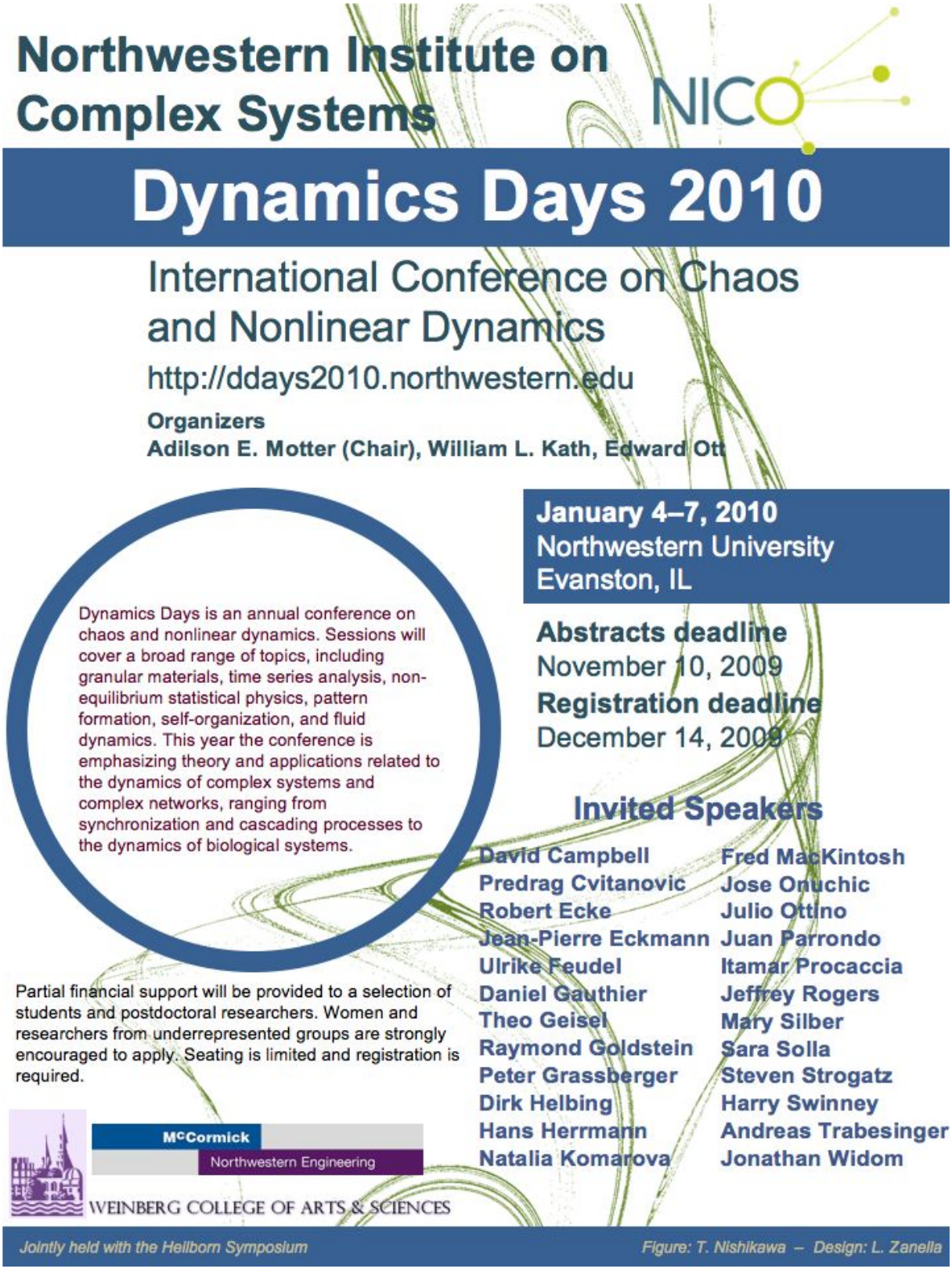
Friday, Jan. 8

Coffee at 3:30 pm, Lectures at 4:00 pm
Ryan Auditorium, Technology Institute
2145 Sheridan Road, Evanston, IL

www.heilbornsymposium.northwestern.edu

co-sponsored by Northwestern University's WCAS, TGS, NICO, C²ST & Adler

Dynamics Days 2010



Alumni

Matt Bierbaum (B.A. 2009) was elected to the Phi Beta Kappa Honor Society.

John Hewitt (PhD. 2009, Farhad Yusef-Zadeh) is currently working an NRC postdoctoral fellow at NASA's Goddard Space Flight Center.

Emmanouela Rantsiou (PhD. 2009, Fred Rasio) has started a postdoctoral position in the Department of Astrophysical Sciences at Princeton University in October.

Benjamin Rolfs (B.A. 2009) was elected to the Phi Beta Kappa Honor Society.

Nicole Carlson (B.A. 2008, Sara Solla and Adilson Motter), is now a Graduate Student at UC Berkeley, and has received a NSF Graduate Fellowship.

Atakan Gürkan (PhD. 2005, Fred Rasio) was awarded a Veni Fellowship at Leiden Observatory (awarded by the Dutch National Science Foundation).

Geralyn "Sam" Zeller (B.A. 1994, PhD 2002) is moving to Fermilab as an Associate Scientist in the Neutrino Department after a stint as a Director's Fellow at Los Alamost National Laboratory. Zeller received the 2003 APS Tanaka Dissertation prize for her measurement of the Weinberg Angle.

Larry Gladney, BA 1980, is now chair of the Department of Physics and Astronomy at the University of Pennsylvania. After participating in the BaBar experiment at Stanford, Gladney is now using HEP techniques to understand Dark Energy. Gladney has received an NSF Presidential Early Investigator award, the Martin Luther King Lecturer award and the Edward Bouchet award from the American Physical Society.

Department Alumni Request:

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 quarterly newsletter. Please send your submissions to Raymond Bailey at rgb@northwestern.edu.

Compiled by Raymond Bailey

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