MILLER INSTITUTE NEWSLETTER

Spring 2008

Miller Fellow Focus: Reimundo Heluani

Second year Miller Fellow Reimundo Heluani studies algebraic and geometric objects motivated by theoretical physics. His work is mainly on Vertex algebras with applications to algebraic and differential geometry. He is hosted by professor Edward Frenkel in the department of Mathematics.

Conformal Field Theory is a very active field in both Mathematics and theoretical Physics. If one wants to study the dynamics of one particle in space-time, their trajectories would describe paths in it, or in other words, maps from a one dimensional line to space-time. In Conformal Field Theories, particles are replaced by strings, or one dimensional objects, hence one is lead to study maps from 2-dimensional surfaces to space-time.

In general, the space of maps from 2 dimensional surfaces to a fixed space M is a complicated object to study, but understanding its structure usually helps one understand the "target" space M itself. It is generally much simpler to describe objects in a local manner, namely, perhaps if we restrict the strings to move in a really small part of M we obtain a simpler theory. After understanding the local picture, one tries to "glue" the whole theory on M from its small parts.

In Mathematics, global objects on a space M that can be described as gluing simpler objects on smaller subspaces of M, are called "sheaves".

Following these ideas, F. Malikov, V. Schechtmann and A. Vaintrob introduced in 1998 the "Chiral de Rham Complex". It is a sheaf of Vertex Algebras on the space-time manifold M. Vertex algebras were introduced by ex-Miller professor Richard Borcherds in 1986. They are similar to usual algebras, having addition and multiplication, but vertex algebras have infinitely many ways of multiplying elements in them, and these multiplications are parametrized by powers of

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Announcement: Call for Nominations

Miller Fellow nominations are due on
Thursday, September 11, 2008

Miller Professor applications are due on
Thursday, September 18, 2008

Visiting Miller Professsor Departmental nominations are due on
Monday, September 22, 2008

Please see the enclosed insert for details on making nominations for the Miller Fellowship program. For complete information on all our programs, visit: http://millerinstitute.berkeley.edu

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z - a complex coordinate in a 2 dimensional surface. The chiral de Rham complex then, assigns to each space-time M such a vertex algebra, and the algebraic properties of this object are intimately related with the geometric properties of the space M.

In a joint article with D. Ben-Zvi and M. Szczesny published in the March 2008 edition of *Compositio Mathematicae*, Dr. Heluani studies extra symmetries (called supersymmetries) that the chiral de Rham Complex (CDR) aquires when the space-time M has special geometries, the more restriced the class of M, the larger the symmetry group of CDR. In particular, when M is HyperKahler, i.e. when we can find three complex structures in M that satisfy the quaternionic relations, CDR has $N = 4$ supersymmetry.

Recently, the connection between Conformal Field Theories and "generalized complex geometries" has been clarified. *Generalized complex manifolds* are obtained when one does not distinguish between position and momenta in phase space. Currently, Dr. Heluani is focused in understanding the supersymmetries of CDR on these spaces.

Vertex algebras are interesting objects by themselves, and as a first step in studying symmetries in CDR, Dr. Heluani, together with his Ph.D. advisor, V. Kac, developed the structure theory of supersymmetric (SUSY) vertex algebras. These algebras are similar to vertex algebras, but their multiplications are parametrized not only by a coordinate z in a surface, but also by a "fermionic" coordinate θ in a supersurface (that is $\theta^2 = 0$).

The formalism of SUSY vertex algebras not only turns out to be very useful to make computations on CDR but also provides a better conceptual understanding of the sheaf itself.

Vertex algebras have been widely studied both by theoretical physicists (under the name of chiral algebras) as much as mathematicians. A very interesting approach is described in the book Vertex Algebras and Algebraic Curves by host E. Frenkel and D. Ben-Zvi. By interpreting the parameter "z" as a complex coordinate in a surface, we can think of vertex algebras themselves as sheaves on these surfaces. It is natural then to think that SUSY vertex algebras should be objects over "super-surfaces", that is, surfaces equipped with functions that "anticommute" under multiplication, just as in fermionic statistic. This approach was carried out in Dr. Heluani's Ph. D. thesis.

The current research of Dr. Heluani focuses in understanding the deep connections between these algebraic objects and other areas of mathematics and theoretical physics. Recently, fascinating connections were found between the theory of vertex algebras (or more generally, chiral algebras) and topology or, more specifically, homotopy theory, a branch of mathematics that studies shapes. This connection allows one to transport several of the tools available in Topology, to the algebraic context. It is in this spirit that Dr. Heluani is involved in fruitful discussions with current first year Miller Fellow Christopher Douglas. Their hope is to use vertex algebras, or purely algebraic objects related to them, to understand *Topological Quantum Field Theories* a version of Conformal Field Theory where one studies maps between surfaces and space-time, but considers only the shapes (or homotopy types) of the spaces involved.

Snapshot from the Spring Dinner

Speaker Yuan T. Lee, Executive Director David Chandler, and Elaine Chandler

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MILLER RESEARCH FELLOWSHIPS FOR 2009-2012 **May 2008**
Nomination *Receipt* Deadline: 11 September 2008 – 4 p.m.

The Miller Institute for Basic Research in Science invites department chairs and faculty advisors to assist the faculty scientists at the University of California at Berkeley by nominating candidates for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. Each Miller Fellow is sponsored by an academic department on the Berkeley campus and performs his or her research in the facilities provided by the host UC Berkeley academic department. The Fellowships are intended for brilliant young women and men of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle.

The deadline for *receipt* of nominations is 4:00 p.m. September 11, 2008. Early nominations are encouraged to allow the candidate more time to prepare their application materials and request references by deadline. An online version of the Nomination Form is available on our website. Submit nominations by email, fax, or mail to the address above and to the attention of the *Selection Committee*. **Incomplete nominations cannot be processed and will be returned to the Nominator for required information.**

Nominations can also be a letter that must include the following information:

1) Nominee's full and legal name
2) Nominee's complete and current E-mail address, current mailing address and telephone & fax numbers
3) Nominee's Ph.D. Institution and (expected) Date of Ph.D.
4) Recommendation and judgment of nominee's promise by the nominator.
5) Nominator's current E-mail address, title, and professional mailing address

This letter of nomination can be of any length, but must include all of the information requested above in order to ensure that nominees receive notification of the nomination and advice of subsequent procedures for completion of the fellowship application process. In addition to the above items, the Executive Committee also finds it helpful in the nomination letter to have the candidate compared with others at a similar stage in their development. Eligible nominees will be invited by the Institute to apply for the fellowship. Direct applications and self-nominations are not accepted. ***Please note that persons already in positions on the Berkeley campus are not eligible for nomination or receipt of an award. Also, nominees who are non-US citizens are contingent upon eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship.*** *The Miller Institute does not support H1B visa status*. The Institute will provide an annual stipend of $60,000 and a research fund of $12,000 per annum. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of $3,000 for removal of personal belongings. The Miller Institute also provides benefits including medical, dental, vision and life insurance. Fellowships are awarded for three years, generally beginning August 1, 2009 and ending July 31, 2012. Approximately eight to ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

Sincerely,

David Chandler
Professor of Chemistry and Executive Director,
Miller Institute for Basic Research in Science

Miller Research Fellowship

Awards 2008-2011

The Miller Institute is pleased to announce the 2008-2011 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2008 academic year.

Pascal Audet
Ph.D. - University of British Coumbia
Berkeley Department: EPS
Faculty Sponsor: Richard Allen

Dr. Audet is interested in the interaction of Earth's tectonic plates at their boundaries where they collide, pull apart, or slide past each other. His research focuses on developing methods in seismology and geophysics to extract information on fundamental processes involved in the evolution and deformation of the Earth.

Philip Hopkins
Ph.D. - Harvard University
Berkeley Department: Astronomy
Faculty Sponsor: Eliot Quataert

Dr. Hopkins research program seeks to develop and test competing pictures for galaxy formation and evolution, in which phases of rapid star formation, quasars, and the simultaneous formation of galactic structure and supermassive black holes represent connected phases in the lives of galaxies.

Prashant Jain
Ph.D. - Georgia Institute of Technology
Berkeley Department: Chemistry
Faculty Sponsor: Paul Alivisatos

Nanostructures of noble metals greatly interest Dr. Jain due to their property of the plasmon resonance, which essentially gives us the ability to confine photons to a nanoscale size. At Berkeley, Dr. Jain will study and utilize the strong "photon-confining" ability of noble metal nanostructures for enhancing optical processes in semiconductor quantum dots, photosynthetic systems, and single molecules.

Isamu Matsuyama
Ph.D. - University of Toronto
Berkeley Department: EPS
Faculty Sponsor: Michael Manga

Dr. Matsuyama has a broad interest in planet formation and evolution. Currently, his main focus is on the rotational stability of planetary bodies in the solar system such as Mercury, Mars and Saturn's moon Enceladus; and the formation of planets (solar and extrasolar) within protoplanetary disks. He is developing models for the reorientation of planetary bodies and the evolution of protoplanetary disks.

Dan Nicolau
Ph.D. - University of Oxford
Berkeley Department: MCB/IB/EECS/Math
Faculty Sponsor: Mimi Koehl

Dr. Nicolau plans to perform research aimed at answering three questions: 1) under what circumstances does evolution produce the optimal solution to a problem? 2) When (and if) the evolutionarily optimal solution is globally sub-optimal, how large is the difference in efficiency between the two? 3) What light can digital evolution shed on the study of biological evolution?

Marcus Roper
Ph.D. - Harvard University
Berkeley Department: Math/PMB/IB
Faculty Sponsor: Jon Wilkening

The goal of Dr. Roper's research is to use asymptotic models and simple experiments to understand fluid dynamical problems, often with biomechanical inspiration. He is especially interested in quantifying the constraints upon organisms that swim, shoot or pump against fluid stresses, including e.g. evolutionary and developmental transitions between locomotory strategies among very small swimmers, and the continuous and adaptive flow of nutrients and nuclear material in fungal networks. Although applications-led, such research can also produce surprising insights into the properties of the equations that are used to describe these systems.

Raman Sanyal
Ph.D. - Technical University Berlin, Germany
Berkeley Department: Mathematics
Faculty Sponsor: David Eisenbud

Dr. Sanyal's research interests lie in the intersection of combinatorics, geometry, and topology. To be precise, his work centers around topological obstructions for the geometric realization of combinatorially given structures. Furthermore, he is interested in the "combinatorial complexity" of discrete-geometric objects.

Eva Schmid
Ph.D. - University of Cambridge
Berkeley Department: Bioengineering
Faculty Sponsor: Dan Fletcher

Many types of cells possess the ability to polarize and move in a directed fashion in response to a gradient of chemoattractant. Dr. Schmid proposes to develop a novel screen to select specifically for mutants in chemotactic steering using a microfabricated "maze" and a mutant library of the model organism Dictyostelium discoideum. Molecules found to be important for steering will then be investigated further to shed light on their function and thepathway(s) they constitute. Finally, the conservation of the identified pathway can be tested in mammalian cells using RNAi.

Rebecca Schulman
Ph.D. - California Institute of Technology
Berkeley Department: Physics/MCB/BioEng
Faculty Sponsor: Jan Liphardt

Dr. Schulman's research seeks to understand complex biological behaviors by building synthetic materials that mimic them. For example, some biological cells use both chemical and physical cues to robustly detect the presence of even a single food molecule or pathogen. She will build a molecular sensor that reacts to a combination of chemical and mechanical information and investigate how it might function better than a simple chemical sensor.

Jonathan Shlens
Ph.D. - UC San Diego
Berkeley Department: MCB / Optometry
Faculty Sponsors: Marla Feller
Bruno Olshausen

A fundamental problem in neuroscience is to understand how populations of neurons represent information about the outside world. Nowhere is this problem more salient than visual signaling from the eye to the brain where roughly one million fibers must faithfully (and efficiently) represent the visual world. Dr. Shlens research is focused on understanding the electrical language of the optic nerve, the 'neural code', by combining recordings from large populations of retinal neurons with ideas and analysis from statistical mechanics and machine learning. His hope is that this work will lead to insights into the 'neural code' in other sensory systems and a better understanding of the computations afforded by populations of neurons.

What do some Miller Fellows do between receiving their PhD and coming to the Institute?

Follow the travels of new Miller Fellow Dan Nicolau on his adventures at: www.fareasternexpedition.com

Next Steps

The Miller Institute congratulates the following Miller Fellows on their next endeavors.

Rannan Fattal
Assistant Professor
Computer Science and Engineering
Hebrew University

Jarmila Pittermann
Assistant Professor
Ecology and Evolutionary Biology
University of California, Santa Cruz

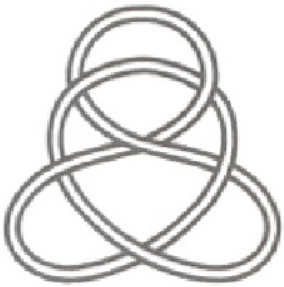
David Shelly
Mendenhall Postdoctoral Fellow
Earthquake Hazards Team
U.S. Geological Survey

Annie Tsong
Scientist
Amyris Biotechnologies

Obituaries

David Gale (Visiting Miller Professor Fall 1965 - Spring 1966, Miller Professor 1971 - 1972), an emeritus professor of Mathematics at UC Berkeley, died March 7, 2008 following a heart attack. He was 86.

Donald Kaplan (Miller Professor 1975 - 1976), an emeritus professor of Botany at UC Berkeley, died December 17, 2007 from complications of pneumonia. He was 69 years old.



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Awards & Honors

April 8, 2008: The first chemistry Solvay chair holder is **Professor Richard Saykally** (Miller Professor 1985 - 1986, 1997 - 1998, Fall 2006). The Solvay professor provides specialized teaching in the chemistry departments of the Université Libre de Bruxelles and the Vrije Universiteit Brussel, as well as an inaugural lecture for a broader audience.

March 13, 2008: **Andrew Streitwieser** (Miller Professor 1964 - 1965, 1979 - 1980) has been selected as a 2008 Senior Scientist Mentor by the Camille and Henry Dreyfus Foundation.

March 13, 2008: **Imke de Pater** (Miller Professor 1993, 2003 - 2004) received the 2007 Chambliss Astronomical Writing Award from the American Astronomical Society for her advanced astronomy textbook Planetary Sciences.

February 26, 2008: **Joshua Shaevitz** (Miller Fellow 2004 - 2007) and **Feng Wang** (Miller Fellow 2005 - 2008) were awarded Sloan Research Fellowships.

February 7, 2008: **Philip Stark** (Miller Professor Spring 1999) was featured in the Berkeleyan for his statistical method of testing election outcomes.

January 30, 2008: The Italian Society of General Relativity and Gravitational Physics (SIGRAV) has awarded **Sergio Ferrara** (Visiting Miller Professor Fall 2008) the Amaldi Medal for his outstanding accomplishments in the construction of supergravity models, in their coupling to matter and in the implications for black holes like the theory of attractors.

August 16, 2007: **Dmitry Budker** (Miller Professor 2002 - 2003) and **Alex Pines** (Miller Professor 1977 - 1978, 1998 - 1999, Spring 2000) were named among R&D Magazine's top 100 innovators of the year for a development in the area of magnetic resonance imaging that could eliminate the need for powerful magnets.

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."