Miller Institute News

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."

Miller Fellow Focus: Bojko Bakalov

Second year Miller Fellow Dr. Bojko Bakalov studies novel mathematical structures motivated by theoretical physics. Dr. Bakalov's research is mainly in algebra but he has also done related work in geometry and topology. He is hosted by Professor Nicolai Reshetikhin in the Department of Mathematics.

Topology is a field of mathematics that studies shapes. In two dimensions, it is concerned with the possible shapes and deformations of surfaces. Let us consider only closed surfaces: spheres, doughnuts, or spheres with several handles attached, but also let us allow holes in them. For example, a sphere with two holes, i.e. two disks cut out from it, is the same as a cylinder. Such surfaces can be sewed together by gluing a hole from the first surface to a hole from the second one. It is easy to see that any surface can be obtained by sewing together disks and spheres with

three holes (called "pairs of pants"). But this can be done in many different ways, and the question arises to describe all possible ways. This "lego game of surfaces" was studied by Dr. Bakalov and Professor Alexander Kirillov Jr. in their book "Lectures on Tensor Categories and Modular Functors" recently published by the American Mathematical Society. The "tensor categories" and "modular functors" are certain abstract algebraic objects arising naturally both in representation theory (which is a part of algebra) and in conformal field theory (a part of theoretical physics). In the book the authors also explore the relations of these structures to the topology of three-dimensional bodies. All this is a part of a complex and profound web that relates many subjects in mathematics and physics. As an historical remark, let us note that the start of this theory was motivated by work of the Miller Institute Executive Committee member Professor Vaughan Jones on the study of

DEADLINE DATES

October 1, 2001   Miller Professor Application

October 4, 2001   Miller Fellow Nomination

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knots (where Professor Reshetikhin has made important contributions as well).

The current research of Dr. Bakalov focuses on other algebraic structures, called "vertex algebras", that were introduced in 1986 by recent Miller Professor Richard Borcherds. In contrast to usual algebra, where one has the operations of addition, subtraction and multiplication, vertex algebras have addition, subtraction, and infinitely many multiplications. All these infinite number of multiplications have to satisfy an infinite collection of complicated identities. To organize them in a neat form, one considers the generating function for the multiplications: a formal series having them as coefficients. In other words, instead of infinitely many multiplications now we have only one, which, however, depends on a parameter z. This parameter can be considered as the coordinate on a surface; thus, we can consider the multiplication as determined by a surface. More precisely, it is given by the "pair of pants": the two legs correspond to the inputs, and the waist to the output. To other surfaces one can assign more general operations. Hence, the vertex algebras are also related to conformal field theory. Although widely known, this relationship is still partially conjectural, and Dr. Bakalov's goal is to understand it deeper. Another aspect of Bakalov's work concerns the purely algebraic study of vertex algebras and related structures called "conformal algebras". The latter are the subject of a 140-page paper, joint with A. D'Andrea and V. G. Kac, which is to appear in Advances in Mathematics.

Bojko Bakalov can be reached at bakalov@math.berkeley.edu.

Miller Fellow Bojko Bakalov

Recent Publications

Michiel Hogerheijde, Miller Fellow ('98 -'01), published seven papers during his fellowship term: From infall to rotation around young stellar objects: A transitional phase with a 2000 AU radius contracting disk?" Astroph. J., 553, 618, "An accelerated Monte Carlo method to solve two-dimensional radiative transfer and molecular excitation; with applications to axisymmetric models of star formation", with M. R. & van der Tak, F. F. S. 2000, Astron. & Astroph., 362, 697, "Testing envelope models of young stellar objects with submillimeter continuum and molecular-line observations", with M.R. & Sandell, G. 2000, Astroph. J., 534, 880, "Detection of H2 pure rotational line emission from the GG Tau binary system", with Thi, W.F., van Dishoeck, E.F., Blake, G.A., and van Zadelhoff, G.-J.,1999, Astroph. J. Letters, 521, L63, "Far-infrared and submillimeter observations and physical models of the reflection nebula Cederblad 201", with Kemper, C., Spaans, M., Jansen, D.J., van Dishoeck, E.F., & Tielens, A.G.G.M. 1999,. Astroph. J., 515, 649, "Sublimation from icy jets as a probe of the interstellar volatile content of comets", with Blake, G.A., Qi, C., Gurwell, M.A., & Muhleman, D.O. 1999, Nature, 398, 213, "Envelope structure of deeply embedded young stellar objects in the Serpens Molecular Cloud", with van Dishoeck, E.F., Salverda, J.M., & Blake, G.A. 1999, Astroph. J., 513, 350.

Recent Publications Continued

Chao-Ping Hsu, Miller Fellow ('98 -'01) completed six papers during her term with the Miller Institute: "Reaction Field Cavity Optimization: A Born-again Born Model for Ionic Hydration", with M. Head-Gordon and T. Head-Gordon, J. Chem. Phys. 111, 9700 (1999), "Electronic Reaction Field Cavity Optimization: Extension to Solvation of Molecules", with M. Head-Gordon and T. Head-Gordon, in Simulation and Theory of Electrostatic Interaction in Solution Ed. by L. R. Pratt and G. Hummer, Proceedings of the Workshop on Treatment of Electrostatic Interactions in Computer Simulations of Condensed Media. American Institute of Physics: N.Y., 1999, pp.350-358, "Femtosecond Dynamics of the Forbidden Carotenoid S_1 State in Light Harvesting Complexes of Purple Bacteria Observed After Two Photon Excitation", with P. J. Walla, P. A. Linden, G. D. Scholes and G. R. Fleming, Proc. Nat. Acad. Soc. 97, 10808 (2000), "Q-Chem 2.0: A High Performance Ab Initio Electronic Structure Program Package", with J. Kong, C. A. White, A. I. Krylov, C. D. Sherrill, R. D. Adamson, T. R. Furlani, M. S. Lee, A. M. Lee, S. R. Gwaltney, T. R. Adams, C. Ochsenfeld, A. T. B. Gilbert, G. S. Kedziora, V. A. Rassolov, D. R. Maurice, N. Nair, Y. Shao, N. A. Besley, P. E. Maslen, J. P. Dombroski, H. Daschel, W. Zhang, P. P. Korambath, J. Baker, E. F. C. Byrd, T. Van Voorhis, M. Oumi, S. Hirata, N. Ishikawa, J. Florian, A. Warshel, B. G. Johnson, P. M. W. Gill, M. Head-Gordon and J. A. Pople, J. Comput. Chem. 21, 1532 (2000), "Excitation Energies from Time-Dependent Density Functional Theory for Linear Polyene Oligomers: Butadiene to Decapentaene", with S. Hirata and M. Head-Gordon, J. Phys. Chem. A 105, 451 (2001), and "Excitation Energy Transfer in Condensed Media", with G. R. Fleming, M. Head-Gordon and T. Head-Gordon, J. Chem. Phys. 114, 3065 (2001).

Birgit Schwickert, Miller Fellow ('99 -'01), wrote one paper during her term with the Miller Institute: "Early Stages of Glacial Clustering in Supercooled Triphenyl Phosphite", with Steven R. Kline, H. Zimmermann, K. M. Lantzky, and J. L. Yarger Phys. Rev. B 64, 045410 (2001).

Adam Summers, Miller Fellow ('99-'01), had a prolific term with the Miller Institute publishing ten articles: "Functional morphology, ecological modeling and feeding specializations – an integrative approach", with Liem, K.F. (2000). Invited submission to Jan Osse Festschrift, Netherlands Journal of Zoology 50(2):245-259, "The evolution of the functional role of trunk muscles during locomotion in adult amphibians", with O'Reilly, J.C., and D.A. Ritter (2000). American Zoologist. 40(1):123-135, "Stiffening the stingray skeleton – an investigation of durophagy in myliobatid stingrays (Chondrichthyes, Batoidea, Myliobatidae)", 2000. Journal of Morphology.243:113-126, "Spadefoot toads (Scaphiopus holbrookii holbrookii) in an urban landscape: effects of non-natural substrates on burrowing in adults and juveniles", with Jansen, K. P., and P. R. Delis. (2001). Journal of Herpetology 35:141-145, "Respiratory modes and mechanics of the hedgehog skate (Leucoraja erinacea) – testing the continuous flow model", with L.A. Ferry-Graham. (2001). Journal of Experimental Biology 204(9):1577-1587, "A clarification regarding the holotype of Caecilia volcani (Amphibia: Gymnophiona)", with M.H. Wake. (2001). Copeia 2001(2): 561-562, "Agassiz, Garman, the Albatross and the deep-sea fishes", with K.E. Hartel and T.J. Koob. [published 2001] (1999). Marine Fisheries Review 61(4): 58-68, "Caecilia volcani species account", (2001) Catalog of North American Amphibians, "The Lobster's Violin – its enough to give a predator pause", Biomechanics Column, Natural History Magazine, June 2001 pp 26-27, and "Spider Webs – from molecule to miracle material", Biomechanics Column, Natural History Magazine, July 2001.

Stephen Zatman, Miller Fellow ('98-'01) published three papers during his term with the Miller Institute: "Analytic models for the dynamics of diffuse oceanic plate boundaries", with Gordon, R. G., and M. Richards, Geophysical Journal International, 145, 145-156, 2001, "On steady rate coupling between an elastic upper crust and a viscous interior", Geophysical Research Letters, 27, 2421-2424, 2000, and "On the dynamical implications of models of B_s in the Earth's core", with J. Bloxham,Geophysical Journal International, 138, 679-686, 1999.

Awards and Honors

James Barber, Visiting Miller Professor (Spring '01), of Imperial College in London was awarded the Flintoff Medal of The Royal Society of Chemistry.

Roger Green, Visiting Miller Professor (Fall '94), of the University of Auckland in New Zealand, and Patrick Kirch, Miller Professor ('93-'94), of the University of California in Berkeley, collaborative project in historical reconstruction of an Ancient Polynesian culture dating 2000-2500 years ago was completed. Their project has been published in a book entitled "Hawaiki, Ancestral Polynesia. An Essay in Historical Anthropology".

Sarah Otto, Miller Fellow ('92-'94), of the University of British Columbia in Canada was awarded the Steacie Fellowship from *NSERC.*

Jean Taylor, Visiting Miller Professor (Spring '99), of Rutgers University, received an honorary doctorate from Mount Holyoke College.