Prof. Rob de Ruyter
Department of Physics
Swain West 117
727 East Third Street
Indiana University
Bloomington, IN 47405-7105

Romulus Breban
1546 S. Beverly Glen Blvd.
Los Angeles, CA 90024
(310) 557 9832
Electronic Mail: *breban@ucla.edu*

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Dear Prof. Rob de Ruyter,

I would like to be given consideration for the Biocomplexity positions in the College of Science at Indiana University announced on the Indiana University web site. I hold a Ph.D. degree in Physics from the University of Maryland, College Park. My specialty area is the theory of low dimensional dynamical systems with emphasis on chaotic dynamics. Also, my most recent interest is in the applications of dynamical systems to Biology which is an aggressively expanding field with great potential. I believe that my educational background and my research skills will not only strengthen the Biocomplexity research at Indiana University, but also enrich it with new directions in the field of chaotic dynamics.

I am attracted to the College of Science at Indiana University by the quality of research and of the graduate programs. I am impressed by the projected expansion of its professorial faculty.

I would greatly appreciate an interview to discuss at greater length the contributions I could make to your Department.

Sincerely Yours,

Romulus Breban

Research Experience

Romulus Breban

My Ph.D. research has focused on topics in low dimensional dynamical systems. While making progress on these different problems, I have greatly benefited from the advice and experience of Profs. Edward Ott and Helena E. Nusse at the University of Maryland, College Park.

I have started the research toward my Ph.D. degree with the topic of Phase Synchronization of Chaos. Phase Synchronization of Chaos distinguishes as a weak interaction between two dynamical systems. From the practical point of view, it offers a new valuable method of testing interdependence between time series, which found numerous applications in Neuroscience and Communications.

My study of Phase Synchronization of Chaos started with sorting out different possible definitions for a phase of a chaotic attractor, and testing them with numerical experiments. Thus, when Prof. Rajarshi Roy and his graduate student David DeShazer presented Prof. Edward Ott and I with laser data to be tested for phase synchronization, I was prepared with a few new data analysis techniques. I did find phase synchronization in the laser data, and our successful collaboration materialized in a publication in the Physical Review Letters.

My next project in Phase Synchronization of Chaos originated as my idea. I asked what happens if a chaotic attractor is subject to two external signals, such that, each of them acting by itself phase synchronizes the chaotic attractor. What I discovered is a new phenomenon of competition between the signals in phase synchronization of chaos. This study has been published in the Physical Review E. After presenting this new theory in front of the Maryland Chaos Group, Dr. Ricardo Meucci and Ryan McAllister from the experimental laser group of Prof. Rajarshi Roy expressed their interest in an experimental search for the new phenomenon of signal competition predicted theoretically. They indeed found the competition phenomenon in a laser experiment, and reported their results to the Physical Review E. More recently, I was invited to talk about the theory of the competition for phase synchronization of chaos at the SIAM Conference on Applications of Dynamical Systems, MiniSymposium of Phase Synchronization of Chaotic Systems: Theory and Applications, Snowbird, UT, May 2003.

All data analysis in Phase Synchronization of Chaos is tested on few numerical examples of phase synchronization of chaotic attractors. However, all these attractors sharing a rather particular morphology (i.e., so-called *phase coherence*) has restricted the practical applications of Phase Synchronization of Chaos. In the literature, phase coherent (i.e., synchronizable) attractors are presented in contrast with *funneling* attractors for which numerical and theoretical efforts towards understanding phase synchronization have failed so far. Following this question, I discovered that, under certain conditions, phase synchronization is manifest for a very large class of chaotic attractors, including all funneling attractors reported in the literature. This work has been reported to the Physical Review E.

Phase Synchronization of Chaos is a new and active field of research where numerous questions await investigation. My interest in this field is broad, regarding both theoretical aspects and applications.

Another major topic of my Ph.D. research is Local Bifurcations on Fractal Basin Boundaries (i.e., so-called *indeterminate local bifurcations*), which has been proposed by Prof. Nusse. We started with the investigation of the indeterminate saddle-node bifurcation. We were motivated by the generic aspects this bifurcation, and its consequences for experimental studies. With this in mind, we were able to characterize features of interest for an experiment detecting an indeterminate saddle-node bifurcation. (Previous work shows that they are common occurrence in dynamical systems.) We have written two papers about our analytical and numerical investigations of this intriguing phenomenon in dynamical systems which have been published in the Physics Letters A and the Physical Review E. We are reporting model-independent mathematical results of broad interest concerning with the dynamical indeterminate saddle-node bifurcation and how it is influenced by noise. I was granted the opportunity to present these results at Dynamics Days 2003, Tempe, AZ, where they received a large audience.

Other types of indeterminate bifurcations like the pitchfork bifurcation and the transcritical bifurcation remain to be addressed by future work.

While doing numerical work for the project of the indeterminate saddle-node bifurcation, I was motivated to study algorithms for computing a fractal dimensions and to propose a new one. Based on theoretical arguments and a systematic numerical investigation for families of one-dimensional maps, this new algorithm is superior to the traditional ones for the case of high dimensions of unstable fractal sets. Graphing the dimension of the basin boundary versus a parameter is a very powerful tool for investigating chaotic dynamics, especially if correlated with the corresponding bifurcation diagram. This is a project Prof. Nusse and I have in mind for the near future.

Besides my research towards my Ph.D. degree, I have always been self-employed with other ideas in physics. In particular, I have a sharp interest in the physics with more than four dimensions and the understanding of the fundamentals of the Quantum and the Statistical Mechanics. My research on this topic has revealed the fact that the Quantum and the Statistical Mechanics of a four dimensional massive particle are just different aspects of a five dimensional quantum propagation of a massless particle. I have summarized my main ideas in a paper called "Interpretation of the Five Dimensional Quantum Propagation of a Spinless Massless Particle" which is now submitted to Annals of Physics.

More recently, I joined the infectious disease modeling group of Prof. Sally Blower at UCLA as a Postgraduate Researcher, and my research interest shifted toward more applied dynamical systems and questions of relevance for the HIV epidemic. The goal of my current research is to use mathematical models and clinical data (blood test results) to extract information about parameters of the HIV infection in a particular patient, and then to predict the patient's response to NNRTI/NRTI treatments. Another ongoing research project is the study of dynamic interactions that may occur between the dynamics of the in-host HIV infection and treatments with periodic interruptions. I am also very interested in the foundations of mathematical modeling in Epidemiology, especially the relation between individual and population level models of epidemic spread.

In my research I am looking forward to the opportunity of collaborations with scientists in both applied mathematics and theoretical physics. I am also looking forward to collaborations with biologists in areas where my background in dynamical systems and modeling may help unravel mysteries of nature.

Romulus Breban
University of California, Los Angeles
Penthouse 2
1100 Glendon Ave.
Los Angeles, CA 90024

Teaching Experience

Romulus Breban

In most of my years of graduate school I was a teaching assistant in physics, leading different types of recitations and laboratory classes. My duty in laboratory teaching was to help students with the experimental work they have been assigned. As a matter of teaching technique, I used to start every laboratory class with a short review of the necessary theory for the current experiment. I believe that the most valuable asset of training in experimental work is independent thinking and physical sense of experiments. I have always stimulated my students to ask questions and search for answers. In general, I found that first giving clues to student questions is a good practice of this idea.

My duty as a teaching assistant for physics courses was answering particular questions every student had about topics discussed in class, and problem solving. I believe that it is often best to offer additional alternate explanations to those found in textbooks. An educator should keep in mind that different students have different backgrounds for understanding physics, and search for the best arguments according to his audience.

In presenting solutions to physics problems, I emphasize the visualization of the setup and teach different ways of tackling with the problem. While elementary problems just probe the basic understanding of physics, it is the more difficult problems that give feedback on the theoretical insight and develop good habits of individual study. I found that a very helpful teaching technique is to present prototype solutions in great detail. Showing students effective ways of approaching a problem versus ineffective ones, and common misconceptions has been successful teaching. Many students found quite useful the clear separation of the physics part from the math part in the solution of a physics problem.

I believe that the role of the teacher is to be a facilitator, that teachers should enable students to become responsible for their own learning. I view teaching introduction to science as a process of encouraging students to make connections between their every day experiences and the subject matter. Teaching of advanced concepts that approach the frontier of knowledge must rely on solid understanding of the fundamentals. I believe that I have dedication for teaching at both undergraduate and graduate levels. Perfecting the methods of teaching is a lifetime effort. I am in great debt to Prof. C.M. Vincent at Pittsburgh University for opening my eyes to this noble profession with his class Teaching of Physics-Practicum.

Appendix: Chronology of Teaching

Semester	Course	Type of Teaching	Course Instructor
Spring 2001	PHYS 262A	Laboratory	Abolhasan Jawahery[1]
Fall 2000	PHYS 262A	Laboratory	Abolhasan Jawahery[1]
Summer 2000	PHYS 121	Recitation and Lab	Kathleen Restorff[1]
Spring 2000	PHYS 121	Recitation and Lab	Jung Ho Paik[1]
Fall 1999	PHYS 121	Recitation and Lab	Satindar Baghat[1], Denis Drew[1]
Spring 1999	PHYS 0110	Recitation	Chandralekha Singh[2]
Fall 1998	PHYS 0577	Honor Laboratory	Rainer Johnsen[2]
Fall 1998	PHYS 2556†	Grading	Jeffrey Winicour[2]
Spring 1998	PHYS 0577	Honor Laboratory	Irving Lowe[2]
Spring 1998	PHYS 2555†	Grading	Jeffrey Winicour[2]
Fall 1997	PHYS 0368	Optics Laboratory	David Snoke[2]

[1] at University of Maryland

[2] at Pittsburgh University

† graduate course