SONYA BAHAR
I apply the physics of nonlinear dynamics and complex systems to the study of collective biological phenomena. My most recent work involves the development of models for the process of speciation in biological evolution. I am particularly interested in how (1) parameters such as mutation rate affect the dynamics of speciation, (2) how evolutionary processes can be characterized using the statistical physics of non-equilibrium phase transitions, and (3) how physics-based approaches can be used to gain insight into the problem of multi-level selection. Other research projects in my group include computational and experimental studies of neural synchronization. Experimentally, we have used voltage-sensitive dyes in order to investigate neural synchronization during focal seizures in the rat neocortex. Computationally, I am currently investigating the onset of “chimera” behavior in neural systems, in which two groups of neurons – despite identical conditions – can be driven to exhibit radically different behavior, with one group synchronized and the other unsynchronized.

Recent Publications:

BERNARD FELDMAN

RICARDO A. FLORES
My research interests are astrophysical cosmology and applications of quantum field theory to the physics of elementary particles. Cosmology is now a well established branch of science thanks in great part to the astounding diversification of Astronomy in the last three decades into observations covering a very broad range of the electromagnetic spectrum. It is also a very exciting field of research due to its inherent intellectual appeal, and the rapid progress allowed by a steady flow of observational data. My most recent published work
was an analysis of large samples of dark matter halos from cosmological simulations to work out their expected properties in the concordance Cold Dark Matter cosmology with dark energy, which is currently favored by a large body of observational evidence. The first work was on the systematics of the shape of DM halos over a wide range in mass, and at different epochs (MNRAS, 367 (2006) 1781). The second work was on comparisons to X-ray observations to test these predictions (MNRAS, 377 (2007) 883). Other work has been on clusters of galaxies (see ApJ 532(2000)206 and ApJ 538(2000)92) and gravitational lensing (see ApJ 533(2000)194 and ApJ 535(2000)555). My work has been funded by the National Science Foundation, the University of Missouri System Research Board, and by Research Awards here at UM - St. Louis. Over the years, I have collaborated on a long-term basis with scientists from around the world to carry out my research. Most recently: Joel Primack @ UCSC (Santa Cruz, USA), and Hernan Quintana @ Universidad Catolica (Santiago, Chile).

PHILIP B. FRAUNDORF

Background and Approach: I’m interested in ways to examine nature on many scales, and how that impacts processes of interest to regional employers as well as problems in nanoscience, Bayesian informatics, and the study of extraterrestrial materials. Methodology and Tools: We use atomic-resolution electron microscopes along with other tools for observing, plus mathematical inference to work from these observations toward conclusions about system behavior on various scales of space and time. Current projects include the quantitative study of contrast in electron images and diffraction patterns of: (i) unlayered graphene in the core of micron-sized particles formed in the atmosphere of red giants, (ii) implantation damage in silicon wafers used to make bonded silicon on insulator (SOI) devices, (iii) nanoparticles and single-strand DNA supported by carbon nanotubes, and (iv) ultrahigh temperature ZrB2 ceramics for hypersonic aircraft leading/trailing edges. We are also applying log-probability based multiplicity tools (esp. Kullback-Leibler divergence) to model selection in general, plus to the study of available work in physical systems and layered correlations in more complex systems. Significance and applications: Methods development in collaboration with regional researchers has helped put graduates into jobs with private sector employers MEMC Electronic Materials (St. Peters MO), Seagate (Minneapolis), Martin-Marietta (New Orleans), Mitsubishi Silicon America (Portland), Motorola’s Digital DNA Lab in Mesa AZ and Cabot Electronics Industries (Napierville IL) along with helping others move to new University assignments here and elsewhere. In the past decade we’ve provided Missouri researchers their only local access to atomic resolution images, helped inspire establishment of the UM-StL Center for NanoScience, and catalyzed regional nanoalliance meetings in St. Louis, Kansas City, and Columbia MO. The program has also given UM-StL researchers access to a wide range of nano-materials, and tools for addressing challenges in healthcare, energy, biology, engineering, and catalysis.

THOMAS F. GEORGE

Dr. George is involved in theoretical research in several areas of laser/materials/nanophysics. One area involves molecular clusters and nanostructures, where excitation processes in fullerenes by ultrafast laser pulses are being investigated theoretically by numerically solving the Liouville equation for electron density matrices. Comparisons are then carried out with experiments in regard to the control of vibrational excitations. Nonlinear optical responses are considered, where femtosecond and picosecond degenerate and nondegenerate four-wave mixing and pump-probe techniques are used to investigate ultrafast electron and nuclear dynamics, charge transfer and photoexcitation in fullerenes. Another area involves the analysis of diamondoids as possible materials for nanoelectronic devices. A recent venture is in nanomedicine, where laser-induced explosion of absorbing gold nanoparticles in selective nanophotothermolysis of cancer is being explored.

Sample recent publications:
ERIKA L. GIBB
Star formation takes place in molecular clouds composed of gas and ice-coated dust. The young stars that form in these environments are surrounded by a disk from which planetary systems are formed. How the gas and icy dust grains evolve physically and chemically during this process is not currently understood. Our solar system has many remnants of this process in the form of comets. Comets retain the volatiles (ices) from the time of formation, and when they pass near the Sun, these ices are released and may be studied. Dr. Gibb uses infrared spectroscopy from the 10-meter Keck telescope in Mauna Kea, Hawaii, to study the chemical composition of volatiles in disks around young stars and comets in our own solar system. In particular, she studies the organic composition in these different environments with the goal of learning how prebiotic molecules (molecules important for the development of life) were distributed in the early solar system. She is also interested in understanding how comets may have contributed to Earth’s supply of ocean water and organics, a potentially vital step in the origins of life on the early Earth. To address this, she is studying deuterated water toward comets and comparing this to Earth’s oceans and formation models of the solar system.

Recent Publications:

BOB L. HENSON
Currently, my activities in the Department are mostly in the areas of instruction at the graduate and undergraduate levels plus service in the curriculum area. These activities have been typical for me for most of my professional life. However, I am still active in theoretical research, but at a somewhat reduced level of activity. I am making progress, but my research projects are problems that have remained unsolved by the physics community for a long time, so success will be coming from long shots. My main scholarly activity now is writing a text on topics in theoretical physics at the senior-graduate level. I am approaching this by writing up
and expanding my class notes for the many advanced undergraduate and graduate level courses, which I have taught many times over the past forty-five years. A secondary goal of my writing is that, although I won the 1998 Governor's Award for Excellence in Teaching, it is my expectation that the writing process will make me a better teacher of mathematical physics.

ERIC MAJZOUB
Our group uses the tools of condensed matter physics for the characterization and theoretical modeling of bulk and nano-crystalline materials. We employ a combined experimental and computational approach, utilizing first-principles techniques to understand the electronic, mechanical, and thermodynamic properties of the materials we study.

Currently, our primary research area is hydrogen storage and Li-ion batteries. These materials are of current interest for energy storage and transportation applications. State-of-the-art hydride materials include NaAlH₄, LiAlH₄, Ca(BH₄)₂, and LiBH₄. These materials are generally wide gap insulators, and are very different in their material properties from interstitial metal hydrides. The complex hydrides undergo decomposition reactions and have more complicated behavior than the so-called “interstitial” metallic hydrides. The compound NaAlH₄ exists as an ionic molecular solid, with AlH₄⁻ anions bound with polar covalent Al-H bonds. Our group studies the structure, lattice dynamics, and thermodynamic properties of these materials to develop higher hydrogen capacities and better hydrogen sorption kinetics. We also develop Monte Carlo global optimization techniques, using advanced methods, which can predict ground state crystal structures and structures close to the ground state in many of the complex anionic hydrides.

Our work in batteries is focused on Li-ion anode materials, where currently graphitic carbon anodes are limited to about 300 mAh/g. Our materials show promising results perhaps with 5-10 times the current capacities.

Recent Publications:
• Tailoring the hydrogen storage properties of Li4BN3H10 by confinement into highly ordered nanoporous carbon X. Liu, E.H. Majzoub, J. Mater. Chem. A, 1, 3926-3931 (2013).

**BRUCE A. WILKING**

Using optical and infrared wavelength imaging and spectroscopy, I study the earliest stages in the formation of low mass stars and substellar objects. We have completed two large optical-wavelength spectroscopic surveys of the surface populations of the Rho Ophiuchi and Serpens molecular clouds using the multi-object spectrographs HYDRA at the WIYN 3.5 meter telescope and HECTOSPEC at the MMT 6.5 meter telescope. The first results of this study for the Rho Ophiuchi cloud, which allowed us to trace the star formation history of the region, appeared in *The Astronomical Journal* in 2005 (v 130, pp. 1733-1751). The follow-up study appeared in *The Astronomical Journal* in 2011, deals with a larger unbiased sample of young stars from which we derive ages and masses and investigate the distribution of masses which exhibits a possible deficit of brown dwarfs. Similarly, the data in Serpens were used to form a more complete census of young stars and investigate the distribution of ages. Unlike the young stars in Rho Ophiuchi, young objects in Serpens show evidence for a spread of 1-5 million years in their ages. Both surveys form the bulk of Kristen Erickson’s Ph.D. dissertation. Most recently, we have begun a collaboration with astronomers at the U.S. Naval Observatory in Flagstaff to analyze infrared images of the Rho Ophiuchi region taken over the past decade in order to derive proper motions and the velocity dispersion for this young star cluster. ([http://www.umsl.edu/~wilkingb/](http://www.umsl.edu/~wilkingb/)).

**Recent publications:**

