**DEPARTMENT OF PHYSICS & ASTRONOMY**
**at**
**THE UNIVERSITY OF MISSOURI-ST. LOUIS**

# FACULTY RESEARCH

(Updated: November 2018)

Here is a brief description of the research activities in which the faculty in Physics and Astronomy are involved.

## SONYA BAHAR

The primary focus of my research is on (1) computational models of evolutionary dynamics and (2) synchronization in neural systems. My students and I are studying phase transitions in evolutionary models, and investigating the effect of parameters like mutation size on the branching of evolutionary lineages. We are also investigating computational models for the evolution of the division of labor, and responses of computational evolutionary systems to simulated mass extinction. On the neural side, we recently published a study of chimera states in a neural model. In a chimera state, identically coupled oscillators form subgroups with fundamentally different dynamical behaviors; such states may provide a simplified model for unihemispheric sleep and sleep apnea. I am also completing a book titled *The Essential Tension*: *From Cooperation and Competition to Multilevel Selection*, which deals with the problem of collective dynamics in biological systems and its implications for evolutionary biology. The book will be published by Springer as part of their "Frontiers" Series, and should appear in 2017.
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*Recent Publications:*

- Glaze TA, Lewis S, Bahar S. Chimera states in a Hodgkin-Huxley model of thermally sensitive neurons. *Chaos*. **26**(8): 083119, 2016.
- Scott AD, King DM, Bahar S. Directed percolation phase transition in a model of neutral evolution. Submitted.
- King DM, Scott AD, Bahar S. Multiple phase transitions in an agent-based evolutionary model with neutral fitness. Submitted.

## BERNARD FELDMAN

My most research interest is in the question of the relationship between cell phone 900 MHz radiofrequency radiation and cancer. I have proposed the following model: the neurons around the brain and heart form closed electrical circuits, and following Faraday's Law, 900 MHz radiofrequency radiation induces 900 MHz electrical currents in these neural circuits. In turn, 900 MHz currents in the neural circuits generate sufficient localized heat in the neural cells to shift the equilibrium concentration of carcinogenic radicals to higher levels and thus, to higher incidences of cancer. These ideas have been published in an article titled "Possible Explanation for Cancer in Rats due to Cell Phone Radiofrequency Radiation," in US-China Educational Review B 6, 609-613 (October 2016). I have also continued to publish pedagogical papers for introductory physics classes, the latest being "An Introduction to Electrodynamics and Special Relativity," US-China Educational Review A6, 380-384 (June, 2016) and "An Introduction to Special Relativity," US-China Educational Review A5, 764-769 (November 2015).

**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 nucleation modeling, as well as 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) atom-thick platelet habit planes in silicon wafers used to make bonded silicon on insulator (SOI) devices, and (iii) nano particles and single-strand DNA supported by carbon nanotubes. Another thread of activity involves software development using github, quite a bit of which involves JS/HTML5 routines for simulating on-line: nanoworld exploration using electron optics, real-time sound visualization including Fourier-phase patterns, and 1-gee travel between stars. We're 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, and helped with regional outreach by the UM-StL Center for NanoScience.

*Recent papers include:*

- P. Fraundorf, Melanie Lipp and Taylor Savage (2016) "Analogs for Unlayered-Graphene Droplet-Formation in Stellar Atmospheres", *Microscopy and Microanalysis* **22**:S3, 1816-1817
  http://www.umsl.edu/~fraundorfp/nanowrld/2016grapheneDropletAnalogs.pdf
  https://hal.archives-ouvertes.fr/hal-01356394
- P. Fraundorf, Stephen Wedekind, Taylor Savage and David Osborn (2016) "Single-Slice Nanoworlds Online", *Microscopy and Microanalysis* **22**:S3, 1442-1443
  http://www.umsl.edu/~fraundorfp/nanowrld/2016NanoworldsOnline.pdf
  https://hal.archives-ouvertes.fr/hal-01362470

- Jamie Roberts, P. Fraundorf, Jai Kasthuri and David Osborn (2016) "Exploring Boltzmann-Factor Distributions of Precipitation-Nuclei in the TEM", *Microscopy and Microanalysis* **22**:S3, 942-943 https://www.cambridge.org/core/journals/microscopy-and-microanalysis/article/exploring-boltzmann-factor-distributions-of-precipitation-nuclei-in-the-tem/AE42BF69AC460231A6E44ABB23FB71B1 https://hal.archives-ouvertes.fr/hal-01367881 http://www.umsl.edu/~fraundorfp/nanowrld/2016boltzmannFactorClusterDistributionsInSi.pdf
- Stephen Wedekind and P. Fraundorf (Sept 2016) "Log complex color for visual pattern recognition of total sound" (patent pending) *Audio Engineering Society Convention* **141**, paper 9647 https://www.linkedin.com/in/stephen-wedekind-488b0327/

**ERIKA L. GIBB**

Comets are icy bodies that formed about 4.5 billion years ago in the outer solar system (beyond the orbit of Jupiter). They were gravitationally scattered by the giant planets into either the Kuiper belt or Oort cloud, distant reservoirs of comets, where they have remained in a frozen state since the beginning of the solar system. Because of this, comets retain the volatiles (ices) from the time of formation, and when their orbits are perturbed and they pass near the Sun, these ices are released and may be studied. Dr. Gibb uses infrared spectroscopy from the 3-meter Infrared Telescope Facility and the 10-meter Keck telescope in Mauna Kea, Hawaii, to study the chemical composition of volatiles in comets. In particular, she studies the organic composition in comets with the goal of learning how prebiotic molecules (molecules important for the development of life) were distributed in the early solar system. She collaborates with scientists who model the chemistry in protoplanetary disks to understand the connection between comet observations and 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:*

- DiSanti, M. A., Bonev, B. P., Dello Russo, N., Vervack, R. J., Jr., Gibb, E. L., Roth, N. X., McKay, A. J., Kawakita, H., Feaga, L. M., Weaver, H. A, "Hypervolatiles in a Jupiter-family Comet: Observations of 45P/Honda-Mrkos-Pajdusakova Using iSHELL at the NASA-IRTF", *The Astronomical Journal*, 154, 146, 2017.
- Bonev, B. P., Villanueva, G. L., DiSanti, M., A., Boehnhardt, H., Lippi, M., Gibb, E. L., Paganini, L., Mumma, M. J., "Beyond 3 au from the Sun: The Hypervolatiles $CH_4$, $C_2H_6$, and CO in the Distant Comet C/2006 W3 (Christensen)", The Astronomical Journal, 153, 241, 2017.
- Roth, N. X., Gibb, E. L., Bonev, B. P., DiSanti, M. A., Mumma, M. J., Villanueva, G. L., Paganini, L., "The Composition of Comet C/2012 K1

(PanSTARRS) and the Distribution of Primary Volatile Abundances Among Comets", The Astronomical Journal, 153, 168, 2017.

**ERIC MAJZOUB**

The research focus of the group is to obtain a theoretical understanding of emergent phenomena. In particular we are interested in the emergence of classical geometry from interacting quantum systems. The overarching goal is to understand the various theoretical approaches to the emergence of spacetime-like mathematical structures. This research field began with two important discoveries. First, black holes were discovered by Beckenstein and Hawking to have a finite (but large) entropy that is bounded by the surface area of the horizon. This led Susskind to the holographic principle – that all the information in a three-dimensional region is contained on the two-dimensional surface bounding that region. The second discovery by Maldecena was the deep connection between gravitational theories in anti-de Sitter space with conformally invariant field theories in one less dimension, known as the AdS/CFT correspondence.

The idea that spacetime is emergent seems to come naturally out of the AdS/CFT correspondence, and also considerations of the quantum mechanics of black holes. Maldecena and Susskind have put forth another conjecture that classical geometry emerges from interacting quantum systems. This area is now of intense interest among theorists. Our interest is primarily in models of interacting quantum systems that in the large N limit lead to emergence of spacetime-like structures.

Current research interests: emergent geometry from large N matrix models, AdS/CFT, non-commutative geometry, entanglement entropy of interacting quantum systems

**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. Most recently, I have been involved in several surveys to characterize the dynamics of the young stellar cluster in Ophiuchus. A 12-year infrared proper motion study of 4 fields in the cluster revealed a relative velocity dispersion of about 1.0 km $sec^{-1}$. An extensive optical radial velocity survey of the Rho Ophiuchi cluster was undertaken led by Dr. Michael Meyer (U. Michigan) in support of ESO's GAIA mission and suggests a similar velocity dispersion over a much larger region. These results point to numerous stellar interactions soon after stars form in small groups. We are following up this result by using infrared echelle spectroscopy to investigate whether the radial velocity dispersion of the young stars increase from the time they emerge from their natal cores. An optical spectroscopic survey of the massive star formation region W4 (IC 1805) is underway. By combining these data with optical and infrared photometric surveys, we will explore the evolution of circumstellar disks in the presence of a strong ultraviolet radiation field.
http://www.umsl.edu/~wilkingb/.

*Recent publications*:

- Rigilaco, E., Wilking, B., Meyer, M. et al., 2016, "The Gaia-ESO Survey: Dynamical Analysis of the L1688 region in Ophiuchus", *Astronomy and Astrophysics*, v588, 12pp
- Wilking, B., Vrba, F., and Sullivan, T. 2015, "Relative Proper Motions in the Rho Ophiuchi Cluster", *The Astrophysical Journal*, v815, 10pp