

“Chemical Nonlinear Dynamics: Oscillations, Chaos, and Synchronization”

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Complex systems often exhibit dynamic self-organization with emergent properties depending on the behavior of the constituent parts and the types and extent of their interactions. In far-from-equilibrium chemical systems such behavior can take the form of temporal and spatial instabilities. For example, the very same diffusion that tends to homogenize concentration differences can also produce cellular, stripe, and zig-zag patterns when coupled to autocatalytic reactions (reaction-diffusion systems). A fundamental challenge of modern science is to understand the workings of complex systems and to explore ways to harvest information to tame the self-organized emergence or breakdown of complex collective behavior.

The seminar will review recent development in nonlinear dynamics in applying chemical reactions to create small networks of dynamical units. The behavior of a single unit is described with traditional kinetic model; relationship between kinetic and dynamical oscillation properties will be presented using bifurcation theory. For a network of units, transition to synchronization is analyzed as a function of network properties. Examples will include organic reactions (e.g., Belousov-Zhabotinsky reaction) and inorganic corrosion systems. Several fundamental forms of synchronization will be presented that include phase waves, emergence of coherence, dynamical differentiation (clustering), and chimera patterns. The results will shed light on the capability of chemical systems to produce rich dynamical patterns that are often associated with living systems. Therefore, emergence of complex, ‘intelligent’ behavior of abiotic systems is possible with oscillatory chemical reactions organized in a network structure.