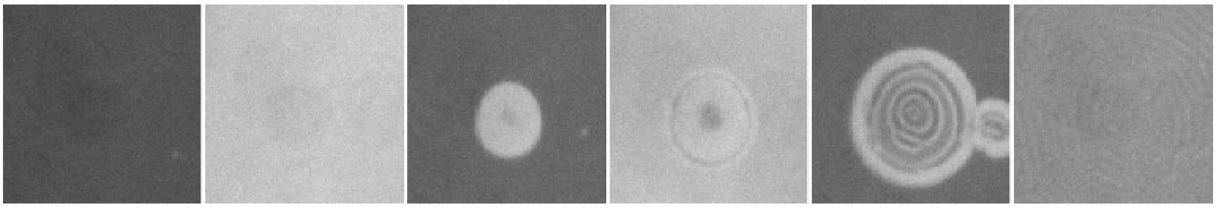
Turing patterns: Experimental pattern growth and invasion

Dynamical Instabilities in the natural world can lead to the formation of interesting and beautiful patterns from spatially uniform conditions. In the Hopf bifurcation, a limit cycle emerges from what was the steady state. This results in a system which exhibits bulk oscillations, uniform in space and periodic in time. In the Turing instability, which is a diffusion-driven instability, the uniform steady state becomes unstable to perturbations of finite wavelength, leading to patterns (Turing Patterns) that are periodic in space and stationary in time. The characteristic wavelength depends on the kinetics and diffusion of reacting species. There are a handful of chemical reactions which can exhibit these patterns in space and time in reaction diffusion systems including the chlorine dioxide-iodine-malonic acid reaction and the Belousov Zhabotinsky Aerosol OT (BZ-AOT) reaction.

The first part of the talk will focus on the transition from one spatially patterned state to one with multi-fold time larger wavelength. Pattern transitions are indicative of change within the system, which, depending on the system, could be catastrophic. An example of this is desertification, where changes in wavelength and morphology of the patterns formed by the patterns formed by the plants are predicted to precede total loss of plant biomass. We report on our study of transitions in Turing patterns in the chlorine dioxide-iodine-malonic acid reaction. This system was modified through additions of sodium halide salt solutions to give a range of wavelengths that are several times larger than in the previously reported literature, which will allow access to a wider range of study of transition phenomena. A transition to a uniform state was found at high halide concentrations. The observed experimental results are qualitatively well reproduced in numerical simulations with the Lengyel-Epstein model with an additional chemically realistic kinetic term to account for the added halide and an adjustment of the activator diffusion rate to allow for interhalogen formation.



The second part will focus on the transition from oscillations in the bulk medium that is invaded by spatial patterns. The Turing and Hopf pattern-forming instabilities can interact with each other, so it is not necessary that these spatial patterns are pure Turing patterns. Some patterns seen in this system, for example oscillatory Turing patterns and oscillatory localized patterns among others, have been attributed to the mixing of modes (MM) from the Turing and Hopf instabilities. We report our experimental results on different MM patterning during invasion including Turing-Hopf fronts and Growing rings in the BZ-AOT reaction which were achieved by varying the volume fraction of the dispersed phase and pH of the aqueous phase. We also connect our results to theoretical predictions.