M.Sc. (Physics) Chaiya Luengviriya

Title:

Dynamics of three-dimensional excitation waves

Abstract

The dynamics of scroll waves and scroll rings in a three-dimensional (3D) excitable chemical medium, the Belousov-Zhabotinsky (BZ) reaction, have been studied. Note that scroll rings are scroll waves with a ring-shaped filament. The investigation is devided into two parts. In part I, two kinds of scroll wave instabilities in homogeneous excitable media, namely 3D meandering and negative line tension instabilities, were studied. In part II, a study of the external control of the dynamics of scroll rings is presented. The control was achieved by an applied electrical current.

Part I: Scroll wave instabilities

Experiments on the dynamics of scroll waves in the BZ reaction have been carried out in an optical tomography setup. This allows for the reconstruction of the 3D structures of the scroll waves and their filament. Using a chemical recipe where the BZ reaction shows meandering waves, the scroll waves with an initially straight filament adopted a flat zig-zag form of constant length. This deformation describes a 3D meandering instability. In this closed system, the reagents were continuously consumed so the system aged. Thus, the second kind of instability, the negative line tension instability, emerged in the long time limit, i.e., at low excitability. Here the filament lengthened substantially and the scroll wave assumed a snaking geometry. Numerical simulations using the generic Barkley model that takes into account the decrease in excitability of the reaction medium due to ageing corroborate the experimental findings and their interpretation.

Part II: Scroll rings in an advective field

In the absence of any external field, scroll rings in the BZ reaction contracted and subsequently self-annihilated at approximately the same orientation and location. The scroll rings were forced to reorient by an applied electrical current, except for two cases – the parallel and anti-parallel orientations, where the orientation is the angle θ between the scroll ring unit vector and the applied current. The parallel orientation ($\theta = 0°$) is unstable against perturbations while the anti-parallel orientation ($\theta = 180°$) is a stable stationary state. The influence of an applied electrical current on the lifetime of scroll rings depends on the initial alignment (θ_0) of the scroll rings. When $0° \leq \theta_0 < 90°$, the lifetime of the scroll rings was shortened otherwise prolonged, compared to that in the absence of electrical current. At the stable stationary orientation ($\theta = 180°$), small scroll rings still contracted, however, larger scroll rings expanded under a given applied current. Numerical simulations using the Oregonator model with an additional advective term accounting for the electric field reproduced the experimental results and provided insights on the deformation of the structure of the filament during the reorientation. Delicate adjustments caused a scroll ring to propagate with a constant radius in an advective field.