Spatiotemporal Chaos in Reaction-Diffusion Systems

M. Bär

Max-Planck-Institut für Physik Komplexer Systeme
Noethnitzer Strasse 38, D-1187 Dresden. Germany

The transition to spatiotemporal chaos is studied in a FitzHugh-Nagumo type reaction-diffusion model (1,2) with excitable and oscillatory kinetics. This model gives a good qualitative description for chemical pattern formation. Consequently, comparisons to experiments are presented. Spatiotemporal chaos is found to originate from instabilities and bifurcation of coherent structures such as traveling pulses in one dimension and rotating spirals in two dimensions.

We employ numerical stability analysis to compute the spectra of pulses and spirals and compare the results with numerical simulations. Stable pulses are replaced by unstable ones in a so-called T-Point bifurcation (3), while simple rotating spirals breakup beyond a linear instability associated with the spectra of the far-field periodic waves (4). Our findings reproduce the far-field breakup related to the Eckhaus instability first studied in the complex Ginzburg-Landau equation and observed experimentally (5) and add core breakup as a second scenario related to a short wavelength instability of the far-field periodic waves. The latter scenario is found also experimentally with the additional complication of spiral core meandering (6). Finally, we discuss possibilities to characterize spatiotemporal chaos by defect statistics and Lyapunov exponents (7).

References:

(1) D. Barkley, Physica D 49, 61 (1991).
(2) M. Bär and M. Eiswirth, Phys. Rev. E 48, 1635 (1993).
(3) M. G. Zimmermann et al., Physica D 110, 92 (1997); M. Or-Guil et al., Phys. Rev. E 64, 046212 (2001).
(4) M. Bär and M. Or-Guil, Phys. Rev. Lett. 82, 1160 (1999).
(5) I. Aranson et al., Phys. Rev. A 46, 2992 (1992); J. M. Flesselles and Q. Ouyang, Nature 379, 143 (1996).
(6) Q. Ouyang, H. L. Swinney and G. Li, Phys. Rev. Lett. 84, 1047 (2000).
(7) M. Hildebrand et al., Phys. Rev. Lett. 75, 1503 (1995); M. C. Strain and H. Greenside, Phys. Rev. Lett. 80, 2306 (1998).