Effects of a defect and drift on dissipative solitons

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In this work we show that a re-entry mechanism leading to excitability can be implemented by adding a defect and drift in a finite system. In this case, when a superthreshold perturbation creates an localized structures (LS) (or dissipative solitons (DS)) on the defect, the drift pulls it out and drives it to the limits of the system, where the LS disappears and the system goes back to the original state. This makes excitability commonplace in systems displaying DS when a defect and drift are introduced. Excitability appears through a number of different mechanism depending on the size of the defect and the intensity of the drift.

We analyze this scenario in the general Swift-Hohenberg equation close to the degenerate Hamiltonian-Hopf bifurcation where DS appear[1]:

$$\frac{\partial u}{\partial t} = -\left(\frac{\partial^2}{\partial x^2} + k_0^2\right)^2 u + c\frac{\partial u}{\partial x} + r(x)u + au^2 - gu^3 + b(x)$$

where u is a real field, $b(x) = hexp\left(-(x-x_0)^2/\sigma^2\right)$ is a defect modeled by a Gaussian function, and c the strength of the drift. $r(x) = r_0 - 1 + exp\left(-(x-x_0)^{18}/\epsilon^{18}\right)$ is a supergaussian profile to model a finite system where the spatial structures advected away by the drift will die at the boundary.

The competition between the defect that produce a pinning of the localized state and the advection term that try to drift the solution away leads to different pinning-unpinning transitions. Fig.1 shows the bifurcation diagram of the localized solutions as a function of the size of the defect h for $c = -0.2$.

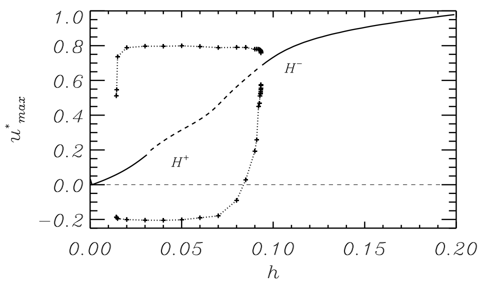

FIG. 1.

For that drift we can see that DS are unpinned from the defect through two Hopf bifurcations. The first one (H^+) is subcritical and leads to a limit cycle where DS grow out of the (low amplitude) fundamental solutions and then are drifted away to die at the boundary of the system, creating a train of soliton or soliton tap[2]. Since the bifurcation is subcritical, the system exhibits Type II excitability. If the system is set below H^+, a perturbation the (low amplitude) fundamental solution grows to generate a DS that is advected away to die at the boundary, and the system comes back to the resting state. An excitable excursion in this case is shown in Fig.2 for $c = -0.7$ and $h = 0.06$.

For larger values of h, large amplitude DS are again pinned to the defect. In this case, decreasing h the drift is eventually able to detach the DS and a new one is formed creating again a cycle in a Hopf bifurcation H^-. In this case the bifurcation is supercritical, showing small oscillations close to threshold, but decreasing h very little this small oscillations become already very large in a sort of canard, creating a source of DS. This is again a mechanism leading to Type II excitability.

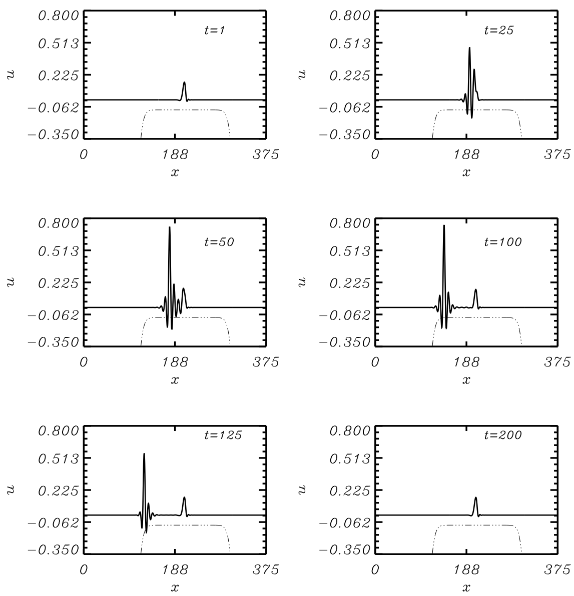

FIG. 2. Excitable excursion close to the H^+ point

This scenario has a third mechanism leading to excitability, namely the SNIC. In this case a (high amplitude) DS is also unpinned leading to the excitable excursion, similar to the case of the supercritical Hopf H^-, but in a Type I fashion.

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[1] P. Woods and A. Champneys, Physica D **129**, 147 (1999).
[2] E. Caboche, *et al.*, Phys. Rev. Lett. **102** 163901 (2009).
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