Competition between drift and spatial defects leads to soliton oscillatory and excitable dynamics

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Dissipative solitons (DSs) are exponentially localized structures appearing in dissipative systems far from thermodynamic equilibrium. DSs are formed due to the balance between nonlinearity and spatial coupling and then driving and dissipation.

DSs can undergo instabilities leading to a wide variety of temporal dynamics, such as periodic oscillations [1] and chaos [2, 3]. It has also been theoretically shown that in nonlinear Kerr cavities, DSs can display excitable behavior despite the fact that the local dynamics (namely the dynamics in the absence of spatial coupling) are not excitable [4]. This differs from systems where excitability is a local property, such as neural models, because excitability is now an emergent property of the DSs. However, while DS excitability may be useful in information processing [5], in two-dimensional (2D) spatial systems oscillatory and excitable DSs are elusive and for most systems only static DSs have been reported. This situation contrasts with one-dimensional (1D) systems such as fiber cavities, where periodic oscillating DSs have been demonstrated experimentally and theoretically [3].

We recently showed that the competition between spatial inhomogeneities and drift provides a way to induce oscillations and excitability of DSs [6]. This competition introduces an oscillatory instability, which can lead to a regime in which DSs are pulled one by one from the defect (referred to as a train of DSs) and to an excitable regime in which the DSs stay pinned in the defect but can be pulled out by a transient perturbation to the system.

Here we build on this work and present a detailed bifurcation analysis of the various dynamical instabilities that result from the competition between a pulling force generated by the drift and a pinning of the solitons to spatial defects [7]. For convenience we will consider the 1D Swift-Hohenberg equation (SHE) for a real field which is a prototypical system that does not exhibit any time-oscillatory dynamics. We show that oscillatory and excitable dynamics of dissipative solitons find their origin in multiple codimension-2 bifurcation points. Moreover, we demonstrate that the mechanisms leading to these dynamical regimes are generic for any system admitting dissipative solitons. Therefore we conclude that oscillatory and excitable dynamics are a general feature for any system admitting DSs in the presence of drift and defects. Such inhomogeneities or defects are unavoidable in any experimental setup, and drift is also often present in many optical, fluid, and chemical systems. In optical systems this can be caused by misalignments of the mirrors, nonlinear crystal birefringence, or parameter gradients, while in fluid and chemical systems drift is due to fluid flow.

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