Excitable population dynamics under fluid stirring: Plankton models in open flows

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Plankton patchiness and plankton blooms are manifestations of the complex nonlinear dynamics of interacting marine populations in which the motion induced by currents and turbulence plays a major role [1]. It was noticed in [2] that population dynamics of the *excitable* type leads quite naturally to some of the observed phenomena.

Here we analyze excitable population dynamics occurring in a moving fluid. We use fluid velocity fields that lead to *chaotic advection* or *Lagrangian chaos* [3], as a simple framework to model stirring and mixing effects occurring in real fluids, and concentrate in the case of open flows. In particular, we consider a vortex-sink model [4] and a geophysically motivated model of a meandering jet [5]. For the species interaction, we consider both the well known FitzHugh-Nagumo activator-inhibitor reaction scheme, and a phytoplankton-zooplankton competition model from [2].

The most striking result is the observation of permanent patterns of excitation (meaning phytoplankton or activator persistence), maintained indefinitely in the system despite the openness of the flow and the intrinsic transient character of excitable dynamics both in unstirred and in homogeneous systems. The excited fluid concentrates in filamental structures that trace unstable manifolds of the chaotic flow dynamics. We present also simplified one-dimensional models [6] aimed at describing the filament structure and we analyze their bifurcations.

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