Multi-bump attractors in a neural field model with two firing thresholds

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Bump attractors emerge in spatially extended models of the cortex, such as networks of spiking neurons or neural field models. They represent localised states of persistent activity that account for experimentally observed phenomena during the delay of spatial working memory tasks. There exist solutions with multiple bump attractors in neural field models with smooth sigmoid firing rate functions, yet they are not analytically tractable. Neural field models with Heaviside step firing rate functions, on the other hand, allow one to obtain analytical solutions for such bump attractors. However, stable multi-bump solutions do not exist in this case due to the repelling behaviour between bumps that results from the lateral inhibition necessary to produce stable bumps.

Here we present a neural field model where the firing rate function is described by two Heaviside step functions. If the shape of the resulting firing rate function does not alter the fixed point structure, then this modification merely provides small quantitative changes to solutions obtained in the one-threshold case. However, if the fixed point structure is altered, specifically if the firing rate of the resting state is non-zero, then we observe the emergence of stable multi-bump solutions. Here, the resting state itself produces inhibition at long distances, which counterbalances the repelling behaviour and equilibrates the bump solutions. Snaking bifurcations organise the number and stability of the emerging solutions, which can be obtained semi-analytically. The threshold conditions and the stability function can be computed analytically (as function of the threshold crossings), and these threshold crossing conditions are then used to numerically produce the bifurcation diagrams. The relatively small number of threshold crossing conditions makes this scheme computationally efficient.