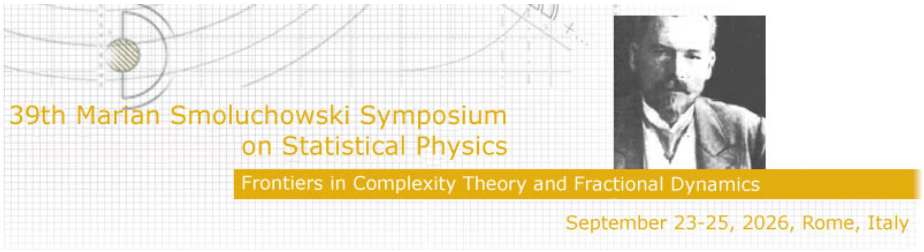

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Phase diagram of Turing pattern formation

Thursday, 24 September 2026 15:30 (1h 30m)

Turing patterns are an example of thermodynamical systems out of equilibrium, exhibiting symmetry breaking and self-organization. Turing in 1952 showed theoretically that in reaction-diffusion under certain conditions a spatially homogeneous stable system can be destabilized by diffusion. Then, a large-scale spatially periodic static pattern emerges. In 1990, Cassettes et al., made the first experimental demonstration of Turing patterns in the chlorite–iodide–malonic acid (CIMA) reaction. Since then, Turing patterns have been proposed across a wide variety of chemical, physical, biological systems.

Just as phase diagrams characterize the different states of matter, Turing space classifies possible patterns. However, due to the nonlinear nature of Turing's conditions the exploration of Turing space is mostly numerical and on a case-by-case basis. Even with the recent implementation of neural networks these techniques are very computationally demanding. It is also often difficult to disentangle dependencies of the pattern on the specific model parameters and compare different models leading to the same pattern.

We propose a new approach to address these problems. First, using the dispersion relation we construct a general solution to Turing's conditions in the linear regime. Second, we show how to rewrite the parameters of any reaction model in terms of our general solution. These provide a common set of parameters for Turing space across models, making it easier to compare candidate models, and to identify universal features of Turing space independent of the model. Moreover, they drastically simplify the numerical exploration, since now it is possible to concentrate first on Turing space only, and on specific regions where a desired pattern is expected. We use CIMA and other models as examples of our formalism and provide numerical validation of our results.

Primary author: LARRAGUIVEL, Helder (UJ, FAIS, Mark Kac Center for Complex Systems Research)

Presenter: LARRAGUIVEL, Helder (UJ, FAIS, Mark Kac Center for Complex Systems Research)

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